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The Economic Significance of Tree Size in Western Sierra Lumbering

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Results of an investigation conducted by the California Forest Experiment Station of the Forest Service, United States Department of Agriculture, in cooperation with the California Agricultural Experiment Station.

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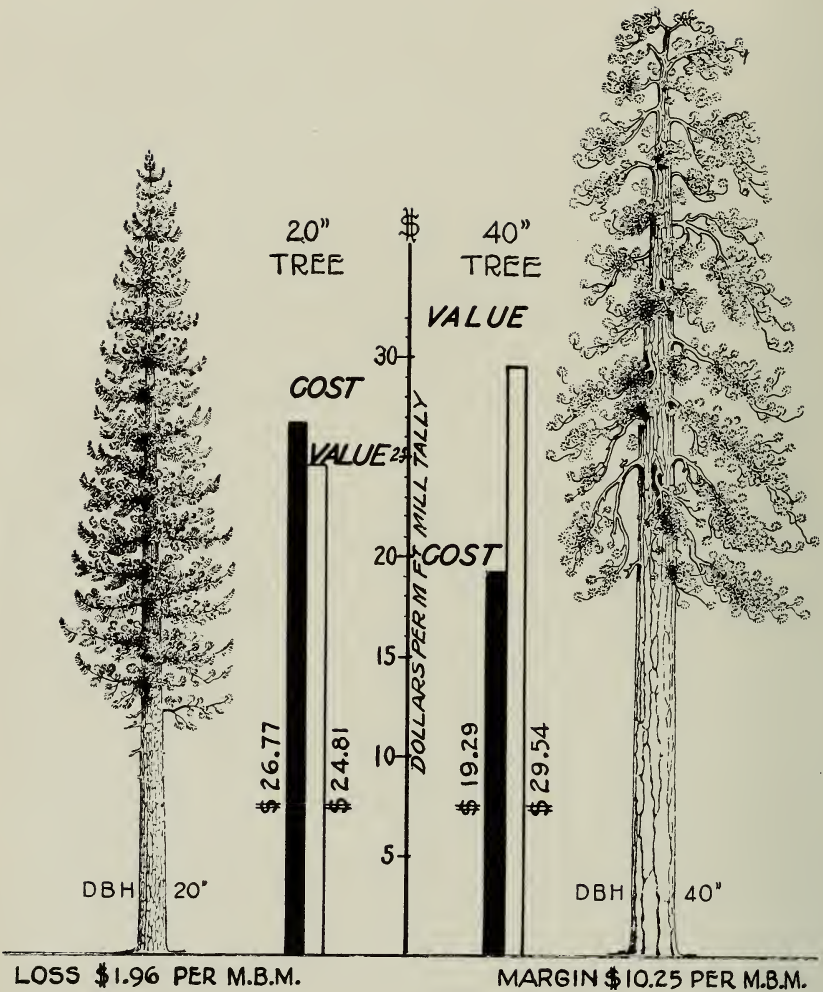

Relation of tree size to costs and values in two ponderosa pines. One thousand board feet of lumber cut from 40-inch trees yielded a margin of $10.25, but the cost of producing that volume of lumber from 20-inch trees was $1.96 greater than its value. The costs given in the graph do not include fixed acre charges, or stumpage.

The Economic Significance of Tree Size in Western Sierra Lumbering[1]

M. R. BRUNDAGE,[2] M. E. KRUEGER,[3] AND DUNCAN DUNNING[4]

INTRODUCTION

Size as an Index of Value.—In the lemon groves of southern California, the picking crews are provided with circular wire gauges having an inside diameter slightly smaller than the diameter of the smallest-sized fruit which will bring a fair profit on the market. The lemon crop is not harvested completely in one picking, or in two pickings, for the lemon tree is continuously sending forth new buds and developing new fruits. Each time the picking crew make the rounds they find lemons in all stages of development. Their instructions are to pick all obviously mature fruit, regardless of size, but in the selction of the green thrifty specimens, they are to pick nothing which will slip through the ring gauge.

It may seem a rather far-fetched analogy, at first glance, to compare lemons with pine trees, for the operation of lumbering is immensely more complex than picking and packing lemons; nevertheless lemon selection illustrates admirably the meaning and the application of economic diameter limit. Not only that, but the removal of overmature and diseased lemons, regardless of size, in order fully to utilize the productive capacity of the tree for growth of sound, thrifty fruit, and to minimize sources of infection, carries a lesson also in desirable forestry practice.

True, the small fruit left for subsequent picking will be large enough for the market in a few weeks or a few months, whereas the small forest tree will not be commercially ripe for many years. But is it good business for a forest owner to cut "any tree that will make a 2 x 4" just because he does not expect to get back over the ground again within his own lifetime? Even though the lemon-grove owner expected to sell his grove in August he would not order his picking crew, as they made

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their last rounds in July, to disregard their ring gauges and bring in everything on the trees, for the very good reason that one box of lemons costing $4.00 and bringing a return of $5.00 yields more net profit than the same box plus another box costing $4.50 and bringing a return of only $4.00.

In the California pine region, the virgin stands contain trees in all stages of development, from the tender seedling to the massive, grizzled veteran whose age may be counted by centuries. In the old days of the bull team, only the choicest trees were cut. As the population grew, lumber prices went up, new machinery was invented, railroad spurs meandered up the draws and along the ridges and there was an ever increasing tendency to cut lower and lower into the small-diameter range. At the present time it is rather common practice on privately owned timberlands in the western Sierra pine region to cut all pine trees down to and including those having butt diameters of only 12 to 16 inches. Is anything gained by harvesting these small sizes, or do they, perhaps, yield an inferior product and entail such high handling costs that their inclusion in the mill-run output has the effect of actually lowering the average annual net profits to the owner or operator? Is it not pertinent to inquire whether the economic principles which apply to the selection of lemons in the California citrus belt may not apply also to the selection of trees in California's commercial pine region?

The Function of Logging and Milling Studies.—It is impossible to answer the foregoing questions from even the most painstaking analysis of the standard operating-cost and selling-value records of the average lumber company. In spite of their elaborate detail with respect to operation subdivisions, the accounts cannot be dissected to show the costs of converting any particular class of raw material into lumber. Though the trees cut and logged may have run all the way from 14 inches to 80 inches in diameter, the figures show only the averages for the entire monthly or seasonal output. Even the cost of one species as compared with another is irretrievably hidden in the averages.

This does not imply that no single item of the total expense can be properly allocated from the usual company records, for there are a few expenditures, such as the annual taxes on the manufacturing plant, which are always converted to an M.B.M.[5] basis by dividing total annual expenditure by total annual production, irrespective of species or the size and class of log from which the lumber is cut; and there are other expenditures—the construction of railroad spurs, truck roads, and woods camps, for example—which may readily be reduced to an M.B.M.

[5] The abbreviation "M.B.M." is used throughout this bulletin for "thousand feet board measure."

basis simply by dividing the total cost for a given area by the total volume in M.B.M. cut from that area. Differences in species of timber or in sizes of logs again do not enter into the calculations, although the cost on an M.B.M. basis varies with the net volume logged to a particular series of spurs or from a particular logging camp.

Incidentally, it is probably the effort to spread this expense, i.e., the initial cost for making a timber tract accessible, over the greatest possible footage of lumber, which has been chiefly responsible for the prevailing practice of cutting small trees on private lands, particularly the pines, down to minimum d.b.h.[6] limits of 12 and 14 inches. The fixed acre[7] operating costs, however, while they appear large for a section of land, or an entire season's logging, ordinarily constitute but 10 to 15 per cent or less of the total conversion charges. The only explanation appears to be that all operators can readily see the favorable effect of greater acre yield on this cost item, while the adverse effect of heavy cutting on a much larger share of the total operating expenses has escaped notice because it is entirely concealed in the annual-statement averages.

But the amount spent by the operator for felling, limbing, bucking, yarding, loading, transporting logs to the mill, unloading, sawing, pulling lumber from the green chain, stacking, seasoning, and subsequent handling will be very different for a tree containing 3,000 board feet than for a tree containing only 300 board feet. This is so obvious that no supporting data are necessary to establish the general fact that these costs do vary with tree size. But to determine just *how much* one tree costs as compared with another requires a cost-keeping system showing almost the same detail for logs and trees of any given species and size class as is shown in the operator's annual statement for the woods-run production. Knowing the cost for, and the volume of, a particular size of tree, it is of course a very simple matter to convert to cost per M.B.M.

Selling values must be segregated in the same way, naturally, if margins for different tree sizes are to be derived. The operator's record shows only the mill-run production of various species, grades, and sizes of lumber. The special record must account for the grades and sizes of material cut from each log and tree.

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[6] The abbreviation "d.b.h." means "diameter breast high" and refers to tree diameter measured outside the bark about 4½ feet above the ground line. Wherever tree sizes are given in this bulletin, d.b.h. is implied.

[7] With efficient planning, there should ordinarily be a decrease in railroad building and an increase in average yarding distance with a decrease in volume per acre cut. In this report, however, fixed acre costs are assumed to be the same, irrespective of the percentage of the stand removed. More comments on this phase will be found under, "Cutting to Different Minimum-Tree-Diameter Limits," page 53.

A logging and milling study is essentially a cost-accounting and value-finding analysis carried to a much greater degree of refinement than the regular bookkeeping system. Such a study may include supplementary records not ordinarily kept by the private operator—logging damage surveys, for example, or special insect and disease research, or growth studies on the woods plots after logging—but its primary aim is to determine the comparative marginal values of the widely varying sizes and classes of raw material found in the commercial forest. The units of study are the individual log and the individual tree.

Some Results of Other Logging and Milling Studies.—Several reports of coordinated logging and milling studies in the eastern half of the United States have been published during the past decade. Stands and conditions studied were radically different from those in the west, however, so no specific results will be cited here. In general, all of the investigations showed that operators were actually paying more for the cutting and handling of many of the smaller trees than they were receiving for the lumber produced from such trees.

In California, Berry(1)[8] found from head-saw time studies made in band-mills during 1914 and 1915 that the time required to cut 1 M.B.M. of lumber from 8-inch[9] and 9-inch logs was almost three times the average for 1 M.B.M. mill run. In a mill in the Plumas National Forest, the 1915 cost of sawing 8-inch logs was $3.68 per M.B.M.; 10-inch, $2.95; 20-inch, $1.73; 30-inch, $1.31; 37-inch, $1.23. This is equivalent to an increase of about 41 per cent in cost per M.B.M. with decrease in log diameter from 37 inches to 20 inches, and an increase of 70.5 per cent from 20 inches to 10 inches. Lumber from the 8-inch logs cost 2.99 times as much to saw as lumber from the 37-inch logs.

Sawing-time studies made by Show(10) a few years later gave a somewhat greater increase in cost with decrease in log diameter—$5.65 per M.B.M. for sawing 8-inch logs, $4.33 for 10-inch, $2.12 for 20-inch, $1.62 for 30-inch, and $1.50 for 40-inch. The lumber from 8-inch logs in this investigation, therefore, cost 3.77 times as much to saw as lumber from 40-inch. The same investigator also calculated comparative sawing costs per M.B.M. for the smaller diameters of trees. The results were: 12-inch trees, $5.65; 14-inch, $4.77; 16-inch, $4.00; 18-inch, $3.73; and 20-inch, $3.45 per M.B.M. This is an increase of 63.7 per cent in the cost of sawing with decrease in tree diameter from 20 inches to 12 inches. The sawing cost per M.B.M. for 20-inch trees was about twice as great as that for 40-inch trees.

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8 Superscript numbers in parentheses refer to "Literature Cited," at end of this bulletin.

9 All log-diameters given in this bulletin refer to the average diameter measured inside the bark at the smaller end of the log.

Concurrent records of lumber-grade production from logs of different sizes obtained by Berry[1] showed the rapid decline in percentage of uppers with decrease in log diameter. Applying these data by log grades and sizes to the woods run of logs from two different cutting systems on the same sample area, he found that the inclusion of small trees cut under private practice reduced the average percentage of uppers from 34.8 to 29.0 in the mill run of sugar pine (*Pinus lambertiana*), and from 40.7 to 37.2 in the mill run of ponderosa pine (*Pinus ponderosa*),[10] as compared with Forest Service cutting, which left practically all of the smaller, limby trees standing. Even with the low selling values of the 1914–1915 period, there was a difference of $1.14 per M.B.M. on sugar pine, and $0.48 per M.B.M. on ponderosa pine in favor of the selective-cutting practice.

Several other mill-production studies have been made by the Forest Service since that time in order that basic timber appraisal data shall conform with changes in cutting practices and grading rules. Price[9] in 1924 calculated the values for ponderosa-pine trees of different diameters in the eastern Lassen region by application of the grade-percentage figures from one of these later studies to stand tables showing the logs in each tree by log grade and diameter. Using 1921–1923 average selling prices, he obtained the following results for different sizes of trees:

D.B.H. IN INCHES	VALUE PER M.B.M.
16	$24.80
24	25.80
30	29.20
40	34.90
50	$37.70

Starting then with the mill-run average value for all trees 12 inches d.b.h. and over, i.e., from clear cutting, the gains in value with successively lighter degrees of cutting were calculated:

PER CENT OF ORIGINAL VOLUME CUT IN TREES 12 INCHES D.B.H. AND OVER	AVERAGE VALUE PER M.B.M. MILL RUN
100.0	$32.86
93.8	33.28
86.1	33.73
75.5	34.21
63.0	$34.61

[10] The common name "ponderosa pine" used in this bulletin refers to the species formerly designated by the common name "western yellow pine."

Each decrease in volume removed was based on the leaving of all trees in progressively poorer thrift classes, not on diameter limits. The lightest cut of 63.0 per cent was all in class 5, defined as "mature and overmature" trees, largely in sizes over 32 inches d.b.h. The heaviest cut next above clear cutting, viz., 93.8 per cent, left only the class 1 trees. These were the trees of most rapid growth, with pointed tops, and numerous small limbs covering 75 per cent or more of the total length and ranging in size from 12 inches to 31 inches d.b.h. Classes 2, 3, and 4 were progressively larger and slower growing.

Felling, limbing, marking, and bucking studies by Bruce[4] showed that these four activities combined cost over three times as much per M.B.M. log scale for 18-inch trees as for 48-inch trees in 1922. The actual costs were $2.05 per M.B.M. for 18-inch trees, $1.07 for 30-inch, $0.78 for 40-inch, and $0.66 for 48-inch trees.

For donkey yarding, Bruce[5] found the cost was five to eight times as much per M.B.M. for 18-inch as for 48-inch trees.

Krueger[8] published, in 1929, the results of tractor-logging studies made on ten different areas in the pine region. With direct tractor skidding, 14-inch logs cost four to five times as much, and 20-inch logs about twice as much, per M.B.M., as 40-inch logs, to yard from stump to landing. In bunching for big-wheel yarding, 22 minutes were required, on the average, to spot 1 M.B.M. gross scale of 12-inch logs, while with 40-inch logs, the time was only 3 minutes per M.B.M. On a log-volume basis, logs scaling 100 board feet cost $1.94 per M.B.M. for bunching as compared with $0.30 per M.B.M. for logs scaling 1,200 board feet. Yarding with caterpillar-tread hydraulic arches cost four to five times as much per M.B.M. for 600 board-foot as for 3,000 board-foot loads. Loads of 1,000 board feet cost a little less than three times as much per M.B.M. as 3,000 board-foot loads.

Hughes,[7] in a fairlead arch wheel study in 1930, correlated yarding costs per M.B.M. with volumes of the average logs in the various loads timed. The cost per M.B.M. for 100 board-foot average logs was $4.11, 500 board-foot logs, $1.02, and 1,600 board-foot logs, $0.64. These figures show that the 100 board-foot size cost approximately four times as much per M.B.M. as the 500 board-foot size, and almost six and one-half times as much as the 1,600 board-foot size.

It will be noted that each of the California studies cited covered only partial phases of the operation of lumbering, i.e., none of them followed the log or the tree all the way from stump to dry-lumber-storage shed or shipping platform. Considered as a whole, however, they furnish substantial evidence that the lumber from the smaller trees in the Cali-

fornia pine region costs the operator considerably more than the lumber from larger trees or from the average tree and is worth considerably less in selling value. The only missing links in the chain of these published reports on California lumbering are the comparative transportation costs for small and large logs from woods-landing to sawmill and the comparative costs and depreciation for trees of different sizes after the lumber is pulled from the green chain.

Of interest to California operators, although not applicable to California stands and conditions, are the reports of coordinated logging and milling studies recently conducted by the Forest Service in central Oregon and in the Inland Empire. In the Oregon study,[(6)] the maximum average margin per M.B.M. between total costs and f.o.b. selling values came from cutting to a minimum tree-diameter limit of 24 inches, inclusive. This removed 73.7 per cent of the total volume in trees 10 inches d.b.h. and over. The stand was practically pure ponderosa pine and the topography was fairly level. A Lidgerwood skidder was used for yarding.

In the Inland Empire,[(2)] the high value of western-white-pine (*Pinus monticola*) No. 1 and 2 Common made it possible to utilize very small trees of this species without sustaining an actual loss[11] although the lumber from 12-inch trees cost nearly 30 per cent more to produce than the lumber from 38-inch trees. The maximum margin per M.B.M. in a sample stand of western white pine was obtained, however, by cutting to a minimum d.b.h. limit of 20 inches. The smallest trees of other species whose values were not below production costs were: ponderosa pine, 16 inches; western larch (*Larix occidentalis*), 18 inches; Douglas fir (*Pseudotsuga taxifolia*), 16 inches; and white fir (*Abies grandis*), 18 inches. Minimum cutting limits for maximum margin per M.B.M. were appreciably above these zero-margin sizes.

The most recent studies in territory adjacent to California are those in the Douglas fir region of Washington and Oregon. A report by Brandstrom[(3)] in 1931, gave comparative woods costs for different sizes of logs and trees and for different methods of yarding. A few of the results, selected at random, are as follows: in felling, maximum production in M.B.M. per man hour was obtained from 48-inch trees; 16-inch trees cost three times as much per M.B.M. for felling and bucking as 36-inch trees; tractor skidding with fairlead arch wheels was the cheapest of seven yarding methods observed; in fairlead arch yarding, the costs for 1,000 feet distance were $1.64 per M.B.M. for logs scaling

[11] The selling values and average operating costs used were for the period 1921–1925, inclusive. All data cited are for sound trees only.

200 board feet, $0.63 for logs scaling 1,000 board feet, and $0.34 for logs scaling 4,000 board feet, which means that the 200-board-foot size cost nearly five times as much per M.B.M. to yard as the 4,000-board-foot size; car-loading costs were $3.85, $1.76, $0.38, $0.21, $0.13, and $0.10 per M.B.M. for logs scaling 50, 100, 500, 1,000, 2,000, and 3,000 board feet, respectively.

Stevens and Bruce[(11)] published, in 1931, an illustrative summary of partial results secured by them in various private lumbering studies for individual operators in different parts of the country. The purpose of the article was to present a bird's-eye view, so to speak, of the scope of selective cutting appraisals for unit operations and the better economic planning made possible thereby. An example from one investigation showed the degree of cutting during the first cycle which would give the greatest possible present worth to the property after discounting average annual realization per M.B.M. at 6 per cent interest. Clear cutting would yield $1.00 per M.B.M. for 20 years giving a present worth of slightly over $500,000, but a 50 per cent cut, i.e., leaving one-half of the original total volume in the small, low-grade trees, but not reducing the annual output of the mill, would yield a net realization of $5.50 per M.B.M. for about 10 years, giving a maximum present worth of $1,900,000. Still lighter cutting—about 25 per cent—would return a profit of $7.00 per M.B.M. but this would last for only 5 years, reducing the present worth to $1,400,000. In the authors' concluding paragraph, they state, "In reviewing some of the work that we have done we have found that the increase in the possible realizations per M.B.M. has ranged from 63 per cent to as high as 500 per cent. The corresponding increase in the present worth of the properties has been from 28 per cent to 232 per cent."

Scope and Purpose of This Bulletin.—This report, limited to a condensed account[12] of current operating economics as related to log and trees sizes, is based on the first completely coordinated logging and milling study to be undertaken by public forest-research agencies in the

[12] By "condensed account," it is meant that the detailed results from the numerous time studies, lumber-grade-production summaries, lumber-depreciation inspections, etc., have been omitted. Being the first study of its kind conducted in California for the information of the public and the lumber industry in general, publication of results has been divided into two distinct types of presentation: (1) a greatly abridged summary for those interested primarily in studying the end results without being distracted by the mass of intermediate technical minutiae upon which they are based, and (2) a compendium of the data from each separate phase of the study suitable for application in determining economic size limits and cutting systems elsewhere in the California west-slope region. This bulletin is the summary report only. The compendium of data for appraisers' use will be made available by the California Forest Experiment Station as soon as possible either in printed or mimeographed form.

California region. Entire trees were traced from the stump to the sawmill lumber-sorting table by a system of numbers placed on the ends of logs prior to yarding. Beyond the green chain, part of the lumber was later reinspected for seasoning degrade and remanufacturing changes by grade, thickness, and width.

Growth studies on the area following logging, special studies of decay and insect losses, and a logging-damage survey were also made a part of the general project. Growth observation will be continued indefinitely as a part of the regular Experiment Station series of permanent sample plots. Although the major objective of the investigation was the determination of comparative tree values in the virgin stand, provision was made in the working plan for study of all factors affecting management of the area from the forestry viewpoint as well as those factors affecting present operating margins only.

As is well known, there is a distinct difference between general conditions in the northeastern part of the California pine region, commonly referred to as the "east slope," and those in the forests bordering the Great Valley west of the Sierra divide, called the "west slope." Variations occur also between different operations in the same subregion. Among the most important variables influencing relative production costs or average values, or both, are (1) volume of stand per acre; (2) type, or mixture of species; (3) range of tree sizes present and the relative proportions of each size by volume; (4) percentage of defect; (5) site quality, or growing conditions; (6) topography; (7) type of logging and kind of equipment used; (8) surface conditions, such as the frequency of rock outcrops, which have an important bearing all along the line, from their effect on breakage in felling to their influence on spur and mainline railroad construction costs; (9) the length of haul between woods and mill; (10) capacity of sawmill and type of sawmill equipment; and (11) lumber-grade selling values f.o.b. mill.

With so many possibilities for variation in the factors governing the margin between expense and income it is evident that no simple rules can be laid down with blanket recommendations for application by all operators in a given lumbering region or subregion. As a matter of fact, a single operator will find it profitable to vary his style of cutting within different units of his own holdings. No claim is made, therefore, that the results of this study represent hard and fast lines of demarcation between the profitable and the unprofitable in all virgin stands of west-slope, Site-1 timber. Nevertheless, they do reflect general trends which are similar throughout the region, for the felling, yarding, sawing, and other partial phases studied by previous investigators show essentially

the same relations between cost and diameter as those resulting from the analysis of the various partial phases in this coordinated study.

The object of this report is primarily to show the cumulative effect of all variables combined as they worked out from the standpoint of operating economics under a particular set of conditions on a unified, complete operation. Summation of the variables is possible only when they are all reduced to the common denominator of dollars and cents. Such procedure has been followed, therefore, in this presentation of the study results. The technical background of *each* variable, if included in full, would be more apt to confuse than to help the reader in obtaining a clear perspective of this cumulative effect of *all* variables.

WOODS-STUDY AREA AND STAND

Description of Area.—The woods-study area, a little over ¼ mile in average width, measured up the slope from the railroad spur, and approximately ½ mile long, measured parallel with the spur, was located in the Stanislaus National Forest, on the North Fork of the Tuolumne River, in Tuolumne County, California. An area of 81 acres was mapped for topography and 73.7 acres was marked for cutting. As may be seen from its position on the outline map of California in figure 1, the area is approximately in the center of the west-slope pine region.

The elevation of the lowest point was 5,680 feet; the highest point was 6,000 feet. The horizontal distance between lowest and highest points was 1,980 feet. The average slope between above points was 16.2 per cent. Maximum slope for a distance of 100 feet was 50 per cent. There were no adverse grades against the tractor loads. Figure 2 is a topographic map of the woods-study area with contours drawn at 10-foot intervals.

The surface was generally smooth without loose rock but with a few fixed boulders or outcrops on the steeper slopes at about middle distance from the landings. The soil was deep and moderately loose.

Site quality was No. 1, i.e., the area was representative of the best growing conditions found in the west-slope pine region.

The Virgin Stand.—The original stand was sugar-pine—white-fir type, based on number of trees. Proportions in each species by volume were radically different from those by tree count, sugar pine (*Pinus lambertiana*) and ponderosa pine (*Pinus ponderosa*) combined constituting 54 per cent of the volume in only 29 per cent of the trees 12 inches d.b.h. and over, while white fir (*Abies concolor*) and incense cedar (*Libocedrus decurrens*), with 71 per cent of the trees, constituted only 46 per cent of the volume.

Fig. 1.—Location of Stanislaus woods-study area.

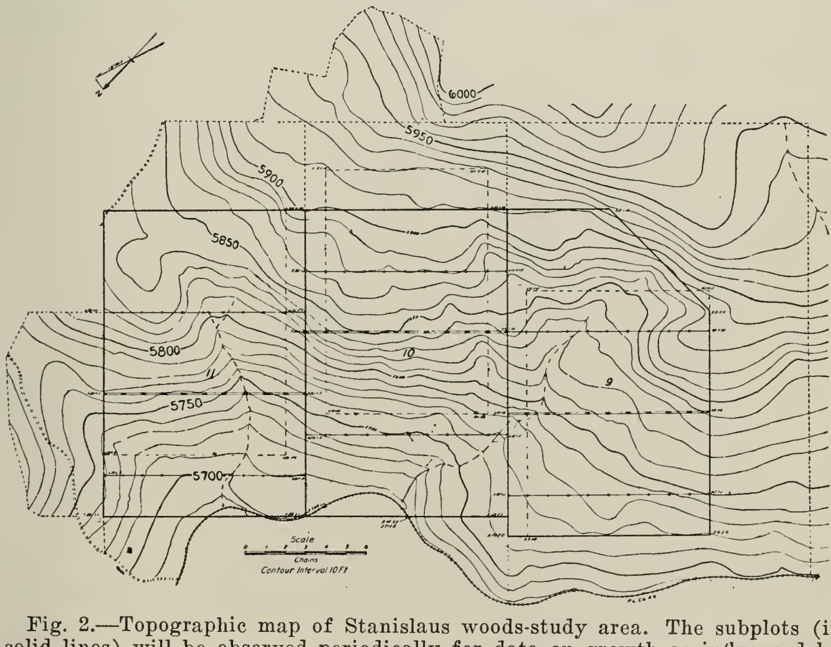

Fig. 2.—Topographic map of Stanislaus woods-study area. The subplots (in solid lines) will be observed periodically for data on growth as influenced by different cutting methods.

Table 1 summarizes the average number of trees and average gross volume per acre of each species in trees 12 inches d.b.h. and over. The volumes, and those in figure 3, are volume-table footages based on d.b.h. and tree-height measurements made prior to felling, and have not been reduced for estimated tree cull or breakage in logging.

TABLE 1

ORIGINAL STAND PER ACRE OF TREES 12 INCHES D.B.H. AND OVER ON THE STANISLAUS STUDY AREA

Species	Trees		Gross volume		Board feet in average tree
	Number	Per cent	Board feet	Per cent	
Sugar pine	8.63	20.61	20,374	34.37	2,361
Ponderosa pine	3.41	8.14	11,690	19.72	3,428
White fir	21.01	50.18	20,585	34.72	980
Incense cedar	8.82	21.07	6,635	11.19	752
Total	41.87	100.00	59,284	100.00	....

Although sugar-pine and white-fir acre volumes were almost the same, there were nearly two and one-half times as many white-fir trees. Ponderosa pine was the largest in average size. The tallest tree was a ponderosa pine 206 feet in total height. The tree of largest diameter was an 80-inch sugar pine. Average heights for selected diameters are shown in table 2.

TABLE 2

MERCHANTABLE HEIGHTS OF STANDING TREES MEASURED TO 8 INCHES TOP DIAMETER IN TREES WITH NORMAL TIPS

D. b. h., in inches	Sugar pine	Ponderosa pine	White fir	Incense cedar
	Heights in 16-foot logs			
20	4.0	3.9	4.3	2.5
30	6.3	6.3	6.4	4.3
40	7.6	7.9	7.9	5.7
50	8.7	9.1	9.0	6.8
60	9.7	10.3	10.0	7.7
70	10.5	11.2	....	....
80	11.0	....	....	....

The large size of the two pine species will be apparent from a study of figure 3, illustrating graphically the comparative total volumes of each species and the proportionate amounts of each by 6-inch d.b.h. groups.

The total volume of both pines was 32,064 feet B.M. an acre. Of this total, 13,272 feet B.M. of sugar pine and 6,620 feet B.M. of ponderosa pine, 19,892 feet B.M. all together, *was in trees 48 inches and over* in diameter breast high. This volume amounts to 62 per cent of the total volume for pines, or 33½ per cent of the total volume for all species.

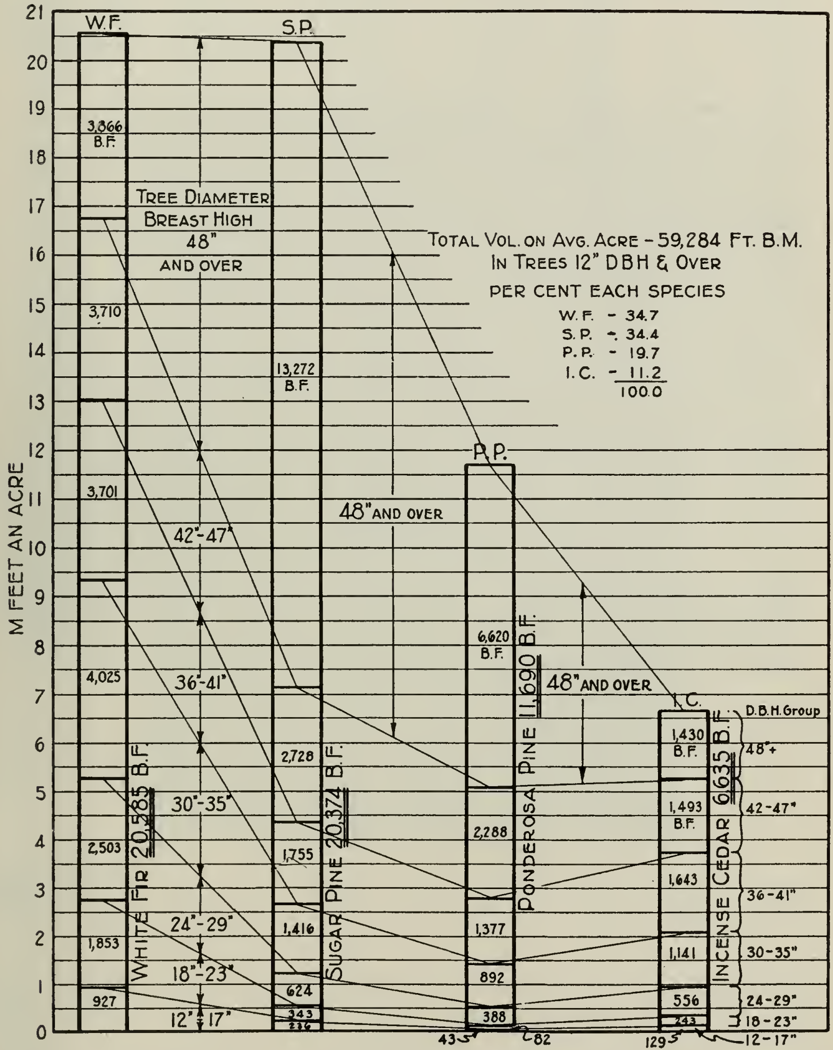

Fig. 3.—Original stand per acre on Stanislaus woods-study area. Comparative gross volumes of each species in trees 12 inches d.b.h. and over, and proportionate volumes by 6-inch diameter groups.

The extremely small proportions of total volumes in trees below 24 inches d.b.h., with the exception of white fir, is plainly brought out by figure 3. This and other facts pertaining to stand composition as shown by the diameter-group volumes and heights of bars have a very important bearing on comparative costs and values of different cutting methods.

Summarizing briefly: the study area of 73.7 acres had a gross cruised volume of 59,284 feet B.M. an acre, 54 per cent of which was sugar pine

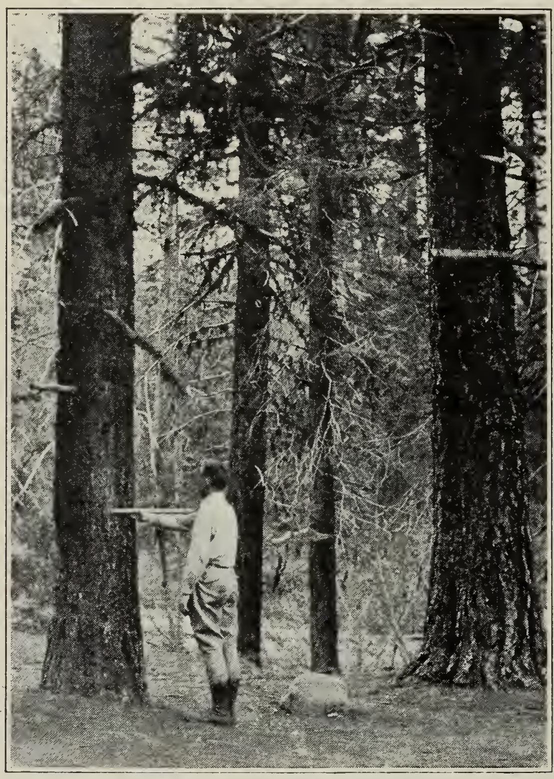

Fig. 4.—Measuring diameter breast high (d.b.h.) with cruiser's stick. The tree being measured is a 22-inch ponderosa pine, the zero-margin size in this species. (See page 51.) The larger tree on the right is a 33-inch ponderosa pine.

and ponderosa pine and 46 per cent white fir and incense cedar. Of the approximately 42 trees per acre making up this volume, one-half were under 24 inches d.b.h. The half over 24 inches contained 93½ per cent of the total volume. One-third of the entire cruised volume was in trees of the two pine species measuring 4 feet d.b.h. and over, and running from 8½ to 11 16-foot logs in merchantable height. There were about

nine of these large pines for every 4 acres, an average of 2¼ trees per acre. This means that 9 pine trees from 48 inches to 80 inches d.b.h. had the same gross scale as 79 trees, all species, ranging between 12 inches and 47 inches in d.b.h., inclusive.

Fig. 5.—On the left, a group of medium-sized, mature pines on the study area. The ponderosa pine in the foreground is about 40 inches d.b.h. On the right, one of the large, high-quality sugar pines. This specimen was 74 inches d.b.h., with 3 grade-1, 3 grade-2, and 4 grade-4 logs. The surrounding advance growth is white fir.

Log Grades.—The standard log-grading rules in use by the Forest Service for timber appraisals in the California pine region are as follows:

Grade 1: Minmum diameter 22 inches on small end and practically surface clear. One or two knots near the end of a log over 36 inches in diameter are permissible if remainder is surface clear. Smaller logs must be surface clear for the full length. Indication of knots near the surface eliminates logs from this grade as effectively as visible knots or limbs.

Grade 2 (Shop logs): Minimum diameter 18 inches on small end. Knots of any size and other blemishes are permissible provided they are so distributed as to produce lumber from which a high percentage of factory cuttings may be obtained. Seventy-

five per cent or more of the surface should be in clear areas at least 8 feet long and 6 inches or more in width, between knots or defects.

Grade 2 is not used for white fir and cedar.

Grade 3: This grade includes all logs smaller than 18 inches in diameter and larger logs too rough in appearance to be admitted in grades 1 and 2.

In this study, the diameter limits were waived and grade 3 was subdivided into grade 3 and grade 4, high-grade Common and low-grade

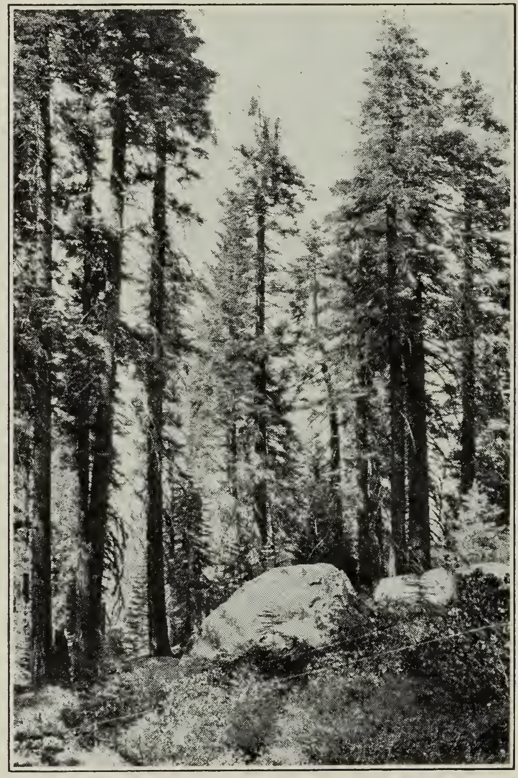

Fig. 6.—A group of mature white-fir trees on the study area. Note defective tops.

Common, respectively. This was done to permit more accurate building up of tree values. For white fir and incense cedar the larger logs which would be a high-type grade 2 in the pine species were also graded as No. 3.

As applied in the study, then, the definitions are as follows:

Grades 1 and 2: Same as above except minimum diameter limits disregarded.

Grade 3: Logs with numerous small, or pin, knots of the types permissible in the grades of No. 1 and No. 2 Common lumber and also, in white fir and incense cedar, logs with a few widely scattered, large knots giving the appearance of the best class pine Shop logs.

Grade 4: Large-knotted, coarse logs and logs with numerous small black, or dead, knots.

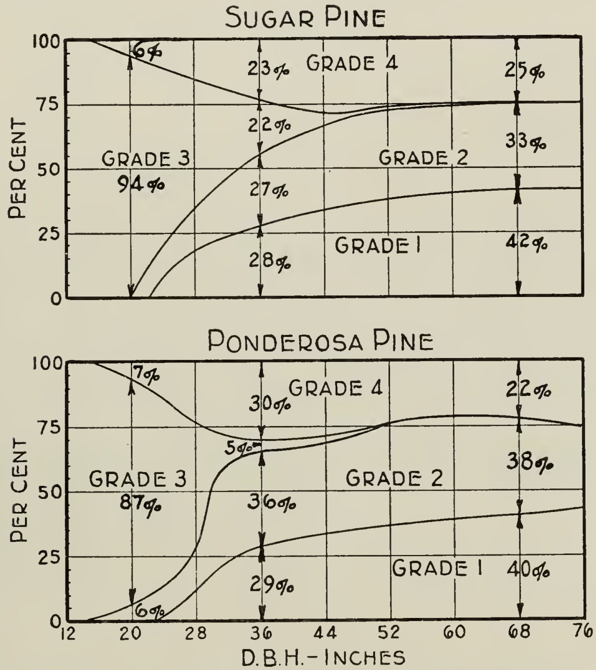

Fig. 7.—Relation of pine-tree size to quality as gauged by the percentages of volume in the various log grades. Percentages in individual log grades are indicated for 20, 36, and 68–inch trees. Cumulative percentages for any diameter may be read from the left-hand scales.

Grade 1 logs produce a high proportion of Selects; grade 2, a high proportion of upper Shop grades; grade 3 is a Common log producing a fairly high percentage of No. 1 and No. 2 Common lumber; grade 4 is the coarse, large-knotted type, producing much No. 3 Shop, No. 3 Common, and No. 4 Common.

Quality of Timber as Indicated by Log Grades.—The quality of a tree from the woodsman's point of view must be gauged by the log grades in the bole. Percentage of volume in each of four log grades for different diameters of both pine species may be read from figure 7.

It will be seen that the pine trees up to 20 inches d.b.h. were largely made up of grade-3 logs. The large pines were of high quality, the pro-

portion of total volume in grade-1 logs being about 25 per cent in the average 32-inch tree and increasing to about 45 per cent in the largest sizes.

An idea of relative average quality by species may be obtained from the following summary showing the percentage of total mill-run volume, gross scale, in various log grades:

	GRADE 1	GRADE 2	GRADE 3	GRADE 4
Sugar pine	35.2	35.3	4.3	25.2
Ponderosa pine	32.4	37.6	4.2	25.8
White fir	18.3	......	43.2	38.5
Incense cedar	10.1	......	30.9	59.0

Study Plots in Relation to Average Logging Areas.—A combination of special study requirements prevented the selection of random plots representing the different types, different sites, and the wide range of topographic conditions always encountered within the boundaries of any large area; consequently, when considered from the standpoint of a company's entire timber holdings, or from that of a season's cutting area, say 1,000 to 4,000 acres, the stand finally selected was somewhat above the average in acre volume and quality. There were no blank spaces or sectors of subnormal merchantibility. However, the effects of such conditions are reflected chiefly in the high selling values of the larger pines and the *average* costs for any given system of cutting and not in the costs—excluding fixed-acre charges—of handling and sawing trees or logs of a particular size class.

STUDY PROCEDURE AND BASIC DATA

Cruising, Mapping, Marking, and Tree Descriptions.—The area was cruised and mapped early in the spring of 1929. The major plot was then divided into three subplots, each to be cut in accordance with a different system. All trees 12 inches d.b.h. and over were numbered, measured, classified, examined for indications of cull and insect damage, and log-graded. The entire area was then marked by all three cutting systems so that later comparisons of relative values would not be invalidated by plot variations.

Felled-tree-analysis records were obtained after the trees were cut. In this work a crew of three measured each log with calipers and tape and drew diagrams of each tree showing breaks, unutilized tops, stump heights, etc., in addition to the data on the merchantable portion. An inventory was taken of trees below 12 inches d.b.h., advance reproduction, brush, and herbaceous vegetation before and after logging. The

three permanent subplots outlined in figure 2 will be remeasured periodically for growth of trees left; losses from windfall, insects, and other causes; development of advance reproduction; establishment of new reproduction; etc.

Felling.—Two-man felling crew time was recorded for each tree cut. Stump heights averaged about 18 inches. The trees timed totaled 926.

Limbing.—Limber's time was recorded for each tree. The trees timed totaled 926.

Bucking.—Bucker's time was recorded for each cut. The largest logs were bucked to 16 feet; the general standard length sought was 32 feet. The cuts timed totaled 1,494.

Yarding.—Caterpillar "60's" were used for yarding. They had no auxiliary equipment. All logs were hooked directly to the tractor drawbar with wire rope chokers and thus skidded from stump to landing. Tractor crew time for each turn was recorded and correlated with distance and scale of load. The trips varied from 4 small logs in one tractor load to single large-log loads requiring the combined pull of three tractors.

The distribution of yarding trips by number of tractors was:

One-tractor trips	2,552
Two-tractor trips	386
Three-tractor trips	15
Total trips timed	2,953

Number of logs in lengths as bucked for yarding	4,054
Total gross scale in yarding study, board feet	3,000,300
Volume of average woods log, gross scale, board feet	740
Number of woods-logs per M.B.M gross scale	1.35
Average volume per tractor-trip, board feet gross scale	1,016
Average volume per tractor-day, board feet gross scale	28,700
Average yarding distance, feet	731
Average external yarding distance, feet	1,200
Longest trip timed, feet	2,100

Loading.—The equipment for loading consisted of a small loading donkey with spreader bar rigging and an "American" full revolving locomotive crane with special log loading boom. End hooks were used on smaller logs, tongs on medium logs, and straps on the largest logs. About 59 per cent of the study logs were loaded with the steam winch

and 41 per cent with the crane. Time in minutes per log for different diameters used in calculating the loading costs was the average of both rigs. The crew on each rig consisted of five men. The number of logs timed was 3,481.

Transportation, Woods to Pond.—The length of haul was about 36 miles. Load records were kept for 418 cars, showing diameter, volume, and species of each log in each load. Average car-load costs were prorated to log diameters on the basis of the percentage of the average load occupied by each size of log.

Decking and Undecking.—Although all study logs were sent to the mill as soon as received from the woods, the operator's practice was to deck near the main pond the excess of daily woods production over the daily mill output, thus accumulating a supply of logs for continuing the sawmill operation for two or three months after the shutting down of woods operations by the winter storms. The total cost of decking was spread over the entire mill run. This average was then prorated to diameter by applying the same ratios of diameter costs per M.B.M. to the average cost as was shown by the loading curve.

Unloading.—Unloading costs are included with pond costs in this report.

Sawmill.—The sawmill was the double-band type, with 10-foot and 9-foot single-cut, steam-operated, head-saws. There was no gang-saw or green-lumber resaw. A steam drag-saw at the top of the log slip was used for bucking long logs into mill lengths. The carriages were equipped with air-dogs. The gang-trimmer was also air controlled. Lumber for the air-drying yard was pulled into units for transfer by overhead monorail to narrow-gauge yard cars. Mill capacity, both sides combined, was 18 to 20 M.B.M. an hour.

Two complete study crews, one for the day shift and one for the night shift, scaled, graded, and timed the sawing of the logs, marked each board for identification on the green chain, and graded, measured, and tallied the lumber.

Separate scaling, log grade and description, sawing-time, and lumber-tally forms were filled out for each log. Numbered logs from the plots were mixed in the pond with unnumbered logs coming in from other settings. Between batches of plot logs, therefore, the study crews were able to keep records for a large number of other logs, which added strength to the general run of mill data. Total pond and sawmill costs for the season were divided by the total number of effective minutes that the sawmill was in operation to obtain the cost per minute for use with the head-saw time studies.

Total volume of material studied by mill crews:

	Logs	Board Feet
Sugar pine	3,048	2,096,000
Ponderosa pine	1,886	1,111,000
White fir	2,607	922,000
Incense cedar	1,005	257,000
All species	8,546	4,386,000

Size of average log, mill run—513.2 board feet

Number of logs per M.B.M.—1.95

Lumber Production.—Lumber was tallied on the green chain by grade, thickness, width, and length. The tally form for each log was then summarized by volume in three board-width groups, viz., 4–11 inches, 12–19 inches, and 20 inches and wider, for each thickness in each grade produced. It was determined later from the depreciation study that the width price differentials, although an appreciable factor influencing relative values on a green-chain-log-tally basis, were reduced to insignificance by the much greater degrade in the wide Selects, the more extensive remanufacture given them, and the practice of making a preponderance of all-width shipments in the Shop grades; therefore the log and tree values in the charts are based on thickness and grade prices only.

Lumber Depreciation.—Representative samples of the lumber were reinspected after seasoning for accuracy of green-chain grading and for depreciation in drying. The grader marked boards for trimming and ripping to remove drying defects and to improve the original manufacture wherever it was clearly advantageous to do so. The volume of material regraded in this manner was as follows:

	Boards	Board Feet
Air dried	22,633	423,312
Kiln dried	6,259	149,407

The only planer depreciation data obtained directly in connection with the Stanislaus project were for 90 M.B.M. of white-fir boards and dimension stock. About one-third of this volume had been in storage for six months. The amount of incense cedar surfaced before shipment is negligible, hence no planer studies were considered necessary for this species. Surfacing depreciation, additional seasoning losses, and storage degrade in pine uppers were worked out from the results of special depreciation studies carried on previously by the California Forest Experiment Station at other mills in the pine region, as explained under "Additional Depreciation of Pine Species," page 25.

The data from all degrade inspections made as a part of the Stanislaus project, which showed the surfaced shipping grades for white fir, and the rough-dry shipping grades for all other species, obtained from each original green-chain grade after allowing for added defects and other changes due to trimming and ripping, were converted to final dry selling values directly applicable to the green-grade production. For

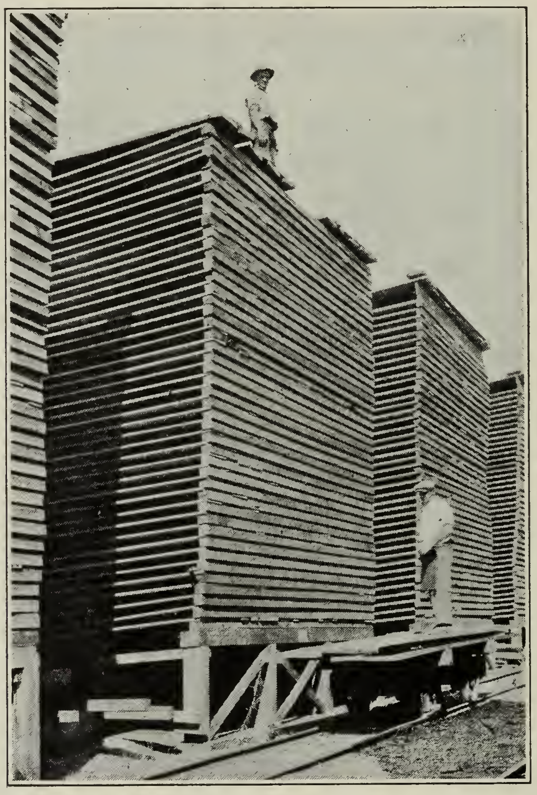

Fig. 8.—Lumber from the study logs, with the green grade marked on every board, was inspected for degrade after seasoning. This photo shows two study piles of 4/4 sugar-pine Selects just before final inspection.

example, 1 M.B.M. of 6/4-inch B and Better sugar pine as tallied in the mill study before seasoning would have a selling value, rough dry, of $82.90 if there were no degrade whatever in drying. Actually, however, some dropped to C Select, some to D Select, some to No. 3 Clear, and smaller proportions to lower grades. Eighteen board feet was lost in trims and rips. The final value of the remaining 982 board feet was $77.24. This is equivalent to the value of 1 M.B.M. green B and Better *discounted for depreciation.*

Evaluation of logs and trees on this basis permitted the use of the curved green-grade lumber-production percentages directly and the conversion of mill tally to log scale by using the green-chain overrun figures without correction for remanufacturing losses.

The relation of these discounted values to the values which would apply if no depreciation occurred between green-chain and shipping shed, is portrayed graphically in figure 9 for trees of each species and diameter. It should be kept in mind that the curves for the two pine species do not include additional depreciation in the upper grades for surfacing, stain, and storage. This has little effect on trees below 30 inches in diameter, however.

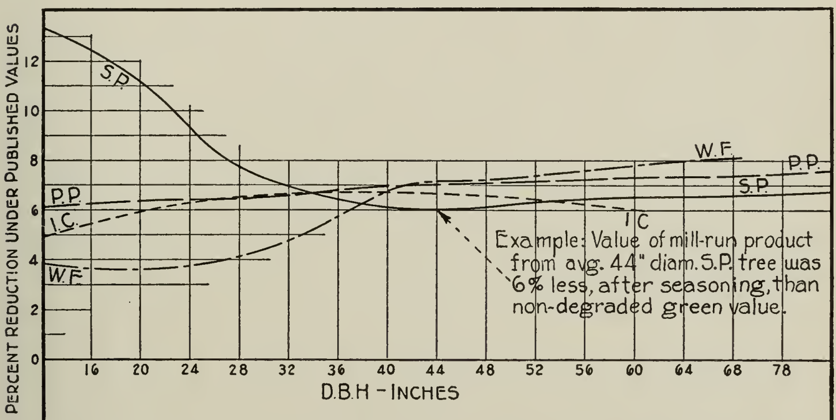

Fig. 9.—Percentage value depreciation in lumber cut from trees of different species and diameters, based on depreciation studies included in the Stanislaus project. See "Additional Depreciation of Pine Species," below, and table 13, for degrade not included in these curves for sugar-pine and ponderosa-pine trees.

Additional Depreciation of Pine Species.—The only really accurate method of determining the *average* final lumber shipping grades for each thickness and grade *as tallied on the green-chain,* particularly at mills where much of the cut is air dried, would involve long-time studies far more intensive than anything yet undertaken by any research agency, public or private, in the California region. West-slope mills usually begin cutting during March or April and continue until some time after the close of the logging season, the date depending on the number of logs stored in decks or in the pond. Storms in the mountains usually prevent further logging after the middle of November. From April to November, December, or January, then, green lumber is continuously going from sawmill to yard-pile or dry-kiln, and dry lumber is continuously going from yard-pile or dry-kiln to outside storage

piles, storage sheds, remanufacturing plant, or shipping platform. Some lumber remains in open seasoning piles for two or three seasons. Some is surfaced before shipment, some is resawed, and some is sold rough.

As all of these variations represent average regional practice, they should be taken into account when attempting to determine grade depreciation for an average season's output.

The lumber depreciation inspections of Shop and Better pine conducted as a part of this study show only the degrade from green to rough-dry during the most favorable period of the year. Board-stain and sticker-stain, causing degrade particularly in B and Better, C Select, No. 3 Clear, and No. 1 Shop are very likely to occur with spring and fall piling, as shown by previous studies at other mills cutting the same type of timber, but there was no stain whatever in the Stanislaus study material. From the results of surfacing studies made at other mills it is also known that further depreciation in value would have been incurred if the Stanislaus study pine uppers had been put through the planer. There is practically no reliable information on storage depreciation, though it is known from observation that stain is apt to be added in solid yard piles and that considerable trimming of checked ends is frequently necessary when grading yard-stored lumber for shipment.

Without going into further detail, it will be apparent to the reader that the pine lumber-grade shipping values fixed by the pine-depreciation inspections made as a part of this study, although accurate enough for lumber cut in midsummer and shipped rough-dry one to six months after stacking, are not representative of the average gross income receivable from the same green grades of lumber over a period of two or three years. Adjustments are clearly called for. They are included in this bulletin as sums to be deducted from the pine selling values calculated on the basis of the Stanislaus degrade studies alone. The deductions for logs of different diameters and grades appear in table 8 and the deductions for trees of different diameters appear in table 13. Deductions for sugar pine include also a seasoning-cost adjustment which is explained in the succeeding section. In computing these deductions, data from other depreciation studies[13] in the pine region were first combined and reduced to percentage stain-plus-surfacing value depreciation factors for each thickness and grade of lumber, storage degrade was estimated as 1 per cent additional in Select grades only, and the average deductions for logs and trees in dollars and cents were

[13] Miscellaneous unpublished reports on file in the California Forest Experiment Station.

then weighted according to the lumber grades produced from each class of logs and trees.

Adjustment of Sugar-Pine Seasoning Costs.—Interest on lumber held in the yard for long periods should perhaps be figured as a cost, especially in connection with sugar pine, to permit of a truer comparison between species. Thick sugar-pine Selects dried in the yard must be left on stickers a long time, whereas ponderosa-pine Selects dried in the kiln are ready for the market in a comparatively short time. Air-dried 16/4-inch sugar pine is rarely in suitable condition for use in less than a year. The thinner Selects require ten times as long to season in the yard as in the kiln. Sugar-pine air-drying costs from this standpoint are probably equal to or higher than kiln-drying costs for ponderosa pine. Rough adjustments to compensate for this fallacy in comparative seasoning costs for the two pine species as shown by ordinary cost accounts have been incorporated in the sugar-pine deductions given in tables 8 and 13. The adjustments are interest charges against the different grade selling values, covering the period of time required for air-drying in excess of the time required for kiln-drying the same thicknesses and grades. The rate of interest used was 6 per cent per annum.

Average Operating Costs.—Logging and milling costs for an average west-slope pine-region operation using direct tractor skidding as the yarding method, having a log haul of 36 miles over standard-gauge, privately owned railroad spurs and mainline, and cutting between 60,000 and 80,000 M.B.M. per annum in a double-band mill are summarized in table 3. The average cut per acre in the general vicinity of the study area, poor timber and good timber combined, over a period of several seasons' operation, is about 30 M.B.M. net scale, and this volume has been used in reducing fixed-acre costs to an M.B.M. basis in the table. The "Total costs per M.B.M." at the end of the table are based on an average cull deduction of 4.83 per cent and an average overrun, No. 5 Common and Better over net scale, of 7.13 per cent. It will be noted that the costs per M.B.M. net scale for different cutting diameter limits on the study plot, as given in figure 24, are all lower than the average net-scale cost in table 3. This is due, of course, to the heavier-than-average stand on the study plots and the larger-than-average size of the trees.

Costs per Minute Used in Converting Time per M.B.M. to Cost per M.B.M.—Stop-watch records of felling time per tree, bucking time per cut, sawing time per log, etc., after changing to time in minutes per M.B.M. for trees and logs of different sizes, were converted to cost per

TABLE 3

AVERAGE OPERATING COSTS FOR 3-YEAR PERIOD 1928–1930

Woods and railroad	Per acre	Per M. B. M. net scale
Felling, limbing, and bucking } including materials and supplies	....	$ 1.22
Yarding, tractor skidding } including materials and supplies	....	1.61
Loading } including materials and supplies	....	0.58
Depreciation logging machinery, prorated to yarding and loading	....	0.35
General camp expense and accident compensation, prorated to all woods costs	....	0.68
General railroad expense, depreciation railroad equipment, and 61 per cent of maintenance	....	0.87
Depreciation of camp buildings and equipment	$ 3.00	....
Fire control	0.25	....
Railroad spur construction	54.69	....
Mainline railroad depreciation	15.00	....
39 per cent of railroad maintenance	11.70	....
Subtotal of fixed acre costs	$84.64	2.82*
Decking and undecking†	....	0.18
Railroad transportation, 36-mile haul‡	....	2.63
Cost of logs delivered to unloading dock	....	$10.94

Sawmill and miscellaneous	Per M. B. M. mill tally
Unloading, pond, sawing, green sorter, kiln-stacking, and general sawmill expense, based on average mill run	$ 2.81
Selling, shipping, insurance, taxes, overhead, and plant depreciation	5.42
Narrow gauge, yard stacking, green yard, dry kiln, unstacking, delivery to shed, remanufacture, dry lumber expense, and surfacing of part, average cost for all species¶	3.30
Total, sawmill, seasoning, and miscellaneous	$11.53

Total costs per M. B. M.	Gross scale	Net scale	Mill tally
Fixed acre costs	$ 2.68	$ 2.82	$ 2.62
Woods and transportation	7.73	8.12	7.54
Sawmill and miscellaneous	11.82	12.42	11.53
Totals	$22.23	$23.36	$21.69

* On cut of 30 M. B. M. per acre.

† Mill log storage, not woods decking.

‡ Includes engine repair, car repair, and train service.

¶ Species differences were as follows:

Species	Air dried	Kiln dried	Rough	Surfaced	Cost per M. B. M.
	Per cent of total		Per cent of total		
Sugar pine	90	10	75	25	$2.65
Ponderosa pine	25	75	40	60	3.92
White fir	78	9	14	86	3.24
Incense cedar	100	0	95	5	$2.04

Remaining 13 per cent of white fir shipped green.

M.B.M. by application of the following costs per minute calculated from the current wage rates and miscellaneous expenses chargeable to each activity:

	Cost per Minute		Cost per Minute
Felling	$0.0273	Yarding	$0.1084
Limbing	0.0110	Loading	0.0950
Bucking	0.0136	Sawmill	0.4327

General camp expense and compensation insurance were prorated to each woods activity in proportion to the relative average cost of each as shown in the annual statement. The bull buck's time was prorated over all felling crews, limbers, and buckers under his supervision. Marker's time was divided equally among all the buckers for whom he marked log lengths. Tractor-boss, choker-setters, tractor-mechanic, and others whose time was chargeable to more than one tractor unit were prorated accordingly. Fuel, and depreciation of equipment are included also in the costs per minute for yarding and loading.

The total of all wages paid to the pond, sawmill, green-chain, and kiln-stacking crews for the entire 1929 season, plus charges for supplies and power used, was divided by the total number of minutes the mill was in productive operation during the season to obtain the cost per minute for both head-rigs combined. This amounted to $0.8655, one-half of which was prorated to each head-rig. Each M.B.M. of mill production for the season absorbed an equal share of plant depreciation, so the latter item is not included in the sawmill cost per minute.

Lumber for the kiln was not pulled from the green chain, but was carried automatically from the end of the table to the kiln stacking shed. Green-chain costs per M.B.M. on the volume pulled for air drying, and kiln-stacking costs on the volume not pulled, were very nearly the same. Handling the costs as above noted is practically equivalent to a full green-chain charge prorated by log diameter to the entire mill output, with no added expense in the kiln-drying costs for stacking the proportion kiln dried.

Lumber Selling Prices.—The California White and Sugar Pine Manufacturers' Association selling-price summaries for the calendar years 1928, 1929, and 1930 are the basis of the average values per M.B.M. shipping tally appearing in tables 4 and 5. The Association prices are for surfaced lumber (except incense cedar Pencil), so in calculating the values of the proportions sold in the rough condition, certain deductions must be made. These are given in footnotes beneath the tables. As explained on page 24, these shipping-tally selling values were discounted for depreciation before application to the green-grade production of logs and trees.

TABLE 4

AVERAGE LUMBER SELLING PRICES* OF SUGAR PINE AND PONDEROSA PINE FOR 3-YEAR PERIOD 1928–1930 PER M.B.M. SHIPPING TALLY

Grade	Thickness in inches					
	4/4	5/4	6/4	8/4	10/4	16/4
	Sugar-pine values					
B and Better	$94.85	$93.14	$85.90	$97.04	$126.65	$140.30
C Select	82.33	75.78	65.67	79.59	120.09	133.12
D Select	66.12	57.14	48.28	66.16	97.27	110.75
3 Clear	48.17	60.51	60.02	77.67	113.92	125.27
Inch Shop	$38.18	....	....	....	....	....
1 Shop	....	42.98	41.77	57.66	90.95	105.58
2 Shop	....	30.92	29.24	35 31	50.15	$ 68.91
3 Shop	....	$23.22	$23.21	$23.05	$ 36.25	....
	Ponderosa-pine values					
B and Better	$70.64	$71.95	$68.30	$76.97	$105.56	$120.79
C Select	65.89	61.75	54.94	64.99	97.40	112.81
D Select	52.95	48.61	40.58	50.63	79.30	95.20
3 Clear	37.35	50.56	50.17	62.24	99.86	113.96
Inch Shop	$28.64	....	....	....	....	....
1 Shop	....	34.83	33.64	46 25	79.24	92.08
2 Shop	....	25.22	25.00	31.72	46.17	62.40
3 Shop	....	$20.03	$21.42	$22.02	$ 34.18	$ 49.56
	Mixed-pine values					
1 Common	$42.98	$48.35	....	....	....	....
2 Common	28.52	32.12	$32.12	$31.63	....	....
3 Common	20.72	22.41	22.41	23.92	....	....
4 Common	$15.04	$16.01	$16.01	$19.02	....	....
5 Common	All thicknesses—$8.62					

* Average selling prices as summarized by the California White and Sugar Pine Manufacturers' Association are for surfaced lumber. The rough-dry prices may be obtained by deducting $3.00 from the values given in the table for the grades of B and Better, C Select, D Select, and No. 3 Clear, $2.00 from the values for No. 1 Shop and No. 2 Shop, and $1.00 from the values given for all other grades.

CULL AND OVERRUN

As this bulletin is not intended for use in making appraisals on other areas, it is not important to present the cull and overrun percentages for each size and species of logs and trees. Use of the Scribner Decimal C log rule for scaling the study logs resulted in the usual high percentages of overrun for the smallest logs and trees.

Table 6 summarizes the percentages of overrun and cull for each species as a whole. Incense cedar had the greatest excess of No. 5 Common and Better tally over net scale and ponderosa pine the least. This was due chiefly to the average thicknesses of lumber cut, over 90 per cent of the cedar being sawed to 10/4-inch pencil stock, while ponderosa pine

TABLE 5

AVERAGE LUMBER SELLING PRICES* OF WHITE FIR AND INCENSE CEDAR FOR 3-YEAR PERIOD 1928–1930 PER M.B.M. SHIPPING TALLY

White-fir values

Grade	Thickness in inches				
	4/4	6/4 and thicker	1 9/16 and 1 5/8	1 3/4 and thicker	All thicknesses
C and Better	....	....	....	....	$39.92
3 and Better Common	$19.98	$21.03	....	....	....
4 Common	13.51	15.79	....	....	....
1 Dimension	....	....	$18.53	$25.54	....
2 Dimenion	....	....	14.74	19.86	....
2 and Better Dimension	....	....	16.34	19.15	....
3 Dimension	....	....	$10.50	$12.70	....
5 Common	....	....	....	....	$ 7.38

Incense-cedar values

Grade	10/4	All thicknesses
C and Better	....	$50.40
3 and Better Common	....	20.50
4 Common	....	12.40
5 Common	....	$ 7.38
1 Pencil*	$25.40	....
2 Pencil*	12.00	....

* All prices are for surfaced lumber except No. 1 and No. 2 Pencil. Deduct $3.00 from C and Better and $1.00 from other grade values, except for the Pencil grades, to obtain rough selling prices.

was sawed principally to 4/4, 5/4, and 6/4-inch lumber, with a much greater proportion of 4/4 and 5/4-inch material than either sugar pine or white fir.

TABLE 6

CULL AND OVERRUN PERCENTAGES* BY SPECIES

Species	All trees 12 inches in diameter and over			All trees 40 inches in diameter and over		
	Cull percentage	Overrun percentage		Cull percentage	Overrun percentage	
		Net scale basis	Gross scale basis		Net scale basis	Gross scale basis
Sugar pine	5.19	4.57	−0.85†	5.69	4.62	−1.34†
Ponderosa pine	2.73	2.42	−0.38†	2.89	2.49	−0.48†
White fir	4.44	5.58	0.89	6.80	5.49	−1.68†
Incense cedar	11.82	29.12	13.86	18.56	31.70	10.30
All species	4.96	6.30	1.03	5.84	5.65	−0.51†

* Cull percentages are based on the volumes scaled at the mill. Cull logs and breakage left in the woods are not included. Overrun percentages are for No. 5 Common and Better.

† Minus sign indicates underrun.

Green trees with less than 25 per cent of merchantable net scale, i.e., cull trees, are not included in the table-6 figures. This class of standing timber, commonly referred to as ''sanitation trees'' on Forest Service timber sales, need not be utilized under government regulations although its cutting is required for stand improvement. Cull trees in incense cedar averaged a little under one tree to the acre. There were no unmerchantable trees, under this definition, in the other species, hence the cull and overrun figures refer to the entire original stand of sugar pine, ponderosa pine, and white fir on the study plot. For incense cedar they refer to 8.03 trees, out of the original stand of 8.82 trees to the acre.

LOG COSTS, VALUES, AND MARGINS

Itemized Costs in Relation to Log Diameters.—On a day-wage basis, all costs for felling, limbing, bucking, yarding, loading, and sawing may be reduced to a fixed sum-per-minute of effective time, irrespective of output during that time. The cost to be charged against a particular log will depend on the number of minutes required to complete the operation for that log. Time in minutes multiplied by cost per minute gives the log cost. The log cost divided by the M.B.M. scale[14] or tally gives the cost per M.B.M. The significance of log size when appraised by this method is portrayed graphically in figure 10 by separate curves of costs per M.B.M. for bucking, yarding, loading, decking, and sawing. A curve of log-transportation costs is also included. Variation in the latter is not determined by time studies, but log diameter has its effect, nevertheless, because the pay-load capacity of a car in M.B.M. is less for small than for large logs.

Five of the curves are for sugar-pine logs and one is for all species combined. Costs for the other species were practically the same as those for sugar pine as far as woods costs are concerned. In the sawmill, white-fir costs were slightly lower than those for sugar pine, incense-cedar costs were appreciably lower, and ponderosa-pine costs were somewhat higher. All, however, showed the same marked tendency to rise very sharply with decrease in log diameters below 20 inches.

The term ''woods logs'' in the charts refers to average lengths as bucked for yarding. Subsequent bucking of long logs into mill lengths was accomplished by a steam drag-saw at the top of the slip.

Costs per M.B.M. for different diameters of logs in figure 10 are on a gross-scale basis with the exception of the sawing curve, which is based on the green-chain tally of No. 5 Common and Better lumber.

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[14] All log-scaling in this study was done with the Scribner Decimal C log-rule.

Compared with the costs per M.B.M. gross scale for 30-inch woods logs, bucking costs were 40 per cent higher for 20-inch, and 191 per cent higher for 10-inch logs; yarding (tractor skidding) costs[15] were 29 per cent higher for 20-inch and 291 per cent higher for 10-inch logs; loading costs were 90 per cent higher for 20-inch, and 602 per cent higher for

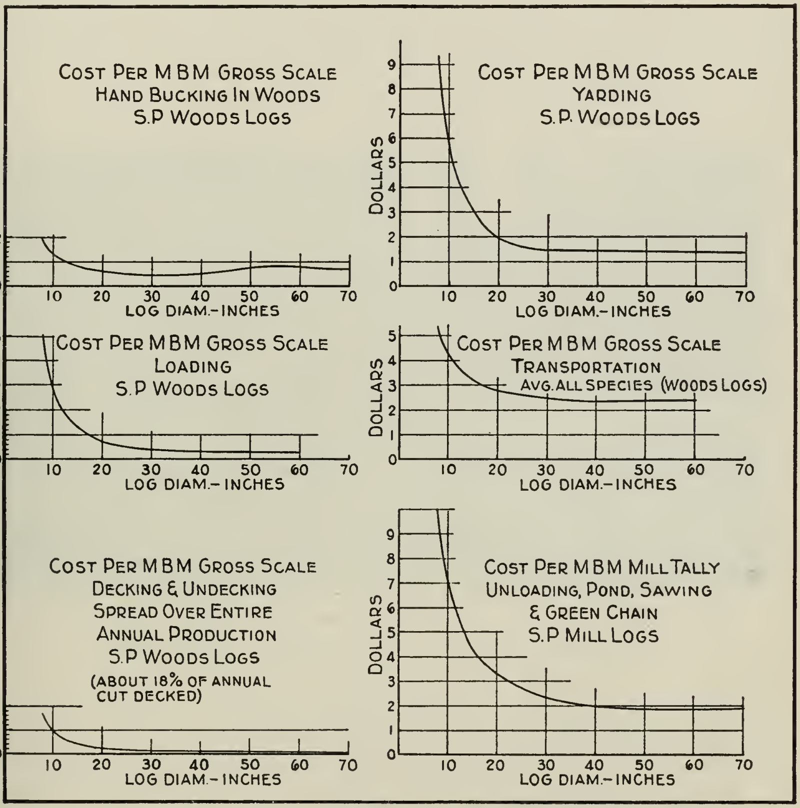

Fig. 10.—The relation of costs per M.B.M. to log diameter. Note the sharp rise of each cost curve over the smaller diameters. Five of the curves reproduced in this figure are for sugar-pine logs (designated "S.P."). Cost curves for the other species were very similar.

10-inch logs; railroad transportation costs were 10 per cent higher for 20-inch and 69 per cent higher for 10-inch logs. Compared with the costs per M.B.M. mill tally for 30-inch mill logs, pond and sawmill costs were 41 per cent higher for 20-inch and 194 per cent higher for 10-inch logs.

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15 Prorating of tractor-trip costs to log diameters in mixed loads was worked out for this report by the method of least squares. Cost per car for railroad transportation was prorated by the same method.

Decking costs at the sawmill, where the smaller and lower-grade logs were stacked for winter sawing, were prorated to diameters on the basis of the loading-cost curve since the two activities were fairly similar as to labor and equipment used.

But the question of most vital importance to the lumber operator in respect to the logs to be cut and delivered to his mill cannot be answered by analysis of costs alone. For each size class and grade of logs he wants to know how the cumulative total of *all costs* compares with the *selling value* of the lumber produced.

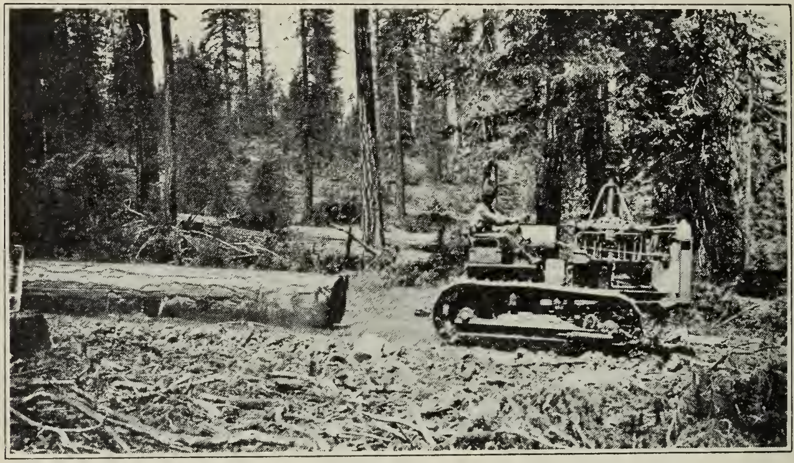

Fig. 11.—Direct tractor skidding from stump to landing—the type of yarding employed on the Stanislaus study area.

Explanation of Cost and Value Curve Diagrams for Logs.—In determining the size of the smallest log just paying its own way, only those costs which will be incurred *after* the tree is felled and ready for bucking should be deducted from the selling value. Felling and limbing costs, therefore, should be temporarily tabled, along with fixed acre expense, for later consideration.

Figures 12, 13, 14, and 15 combine the costs per M.B.M. of bucking, yarding, loading, transportation, decking, unloading, pond, sawmill, seasoning, overhead, and miscellaneous fixed M.B.M. expenses, all on a mill-tally, mill-log basis, for each log diameter of each species in curves labeled, "woods plus mill costs." Broken-line curves of "woods costs" have been inserted to indicate the line of demarcation between bucking-to-pond and pond-to-lumber-shipping costs. Selling-value curves for each log grade in the same diagrams show clearly the relation between costs and values for every diameter. The selling value of 1 M.B.M.

green-chain tally for any size and grade may be read directly from the left-hand dollar scale. Deducting from this figure the "woods plus mill cost" for the same size, read from the same scale, leaves the sum representing the gross margin between operating costs, starting with bucking, and selling value as calculated from the production and seasoning studies.

The more important factors influencing basic costs and values which were described in preceding sections are repeated here for ease of reference by the reader when reviewing the charts and tables.

1. The method of yarding was entirely direct tractor skidding; there was no big-wheel, fairlead-arch, or other special equipment.

2. The average skidding distance was about 750 feet on the study area. The longest hauls were 2,000 to 2,100 feet, but the average external distance from the landings was about 1,200 feet. All yarding costs are for the average skidding distance.

3. Length of log haul over standard-gauge railroad to the mill was 36 miles.

4. Method of sawing was entirely a headsaw operation. There was no gangsaw or green cant resaw.

5. Lumber selling prices used are the averages for 1928–1930. Wage rates, etc., are for the same period.

Cumulative Costs for Logs.—Relative costs of logging and milling different sizes of logs of each species are given in table 7. These are identical with the chart cost-curve values, and do not include felling, limbing, fixed-acre cost, or stumpage.

TABLE 7

Relative Costs per M.B.M.* for Logs of Different Diameters

Mill-log diameter in inches	Sugar pine	Ponderosa pine	White fir	Incense cedar
8	$36.51	$37.89	$36.99	$34.95
10	28.51	29.83	28.63	28.46
12	24.78	25.94	25.77	23.01
14	22.48	23.77	22.86	20.60
16	21.06	22.39	21.21	18.79
18	19.89	21.27	20.05	17.27
20	18.77	20.27	18.81	16.21
30	16.43	17.82	17.20	15.22
40	15.86	17.34	16.62	$15.65
50	16.02	17.25	$16.70	....
60	16.15	$17.36	....	....
70	$16.15	....	....	....

* Bucking to lumber shipping, inclusive. All costs are on an M. B. M. green lumber tally basis, No. 5 Common and Better.

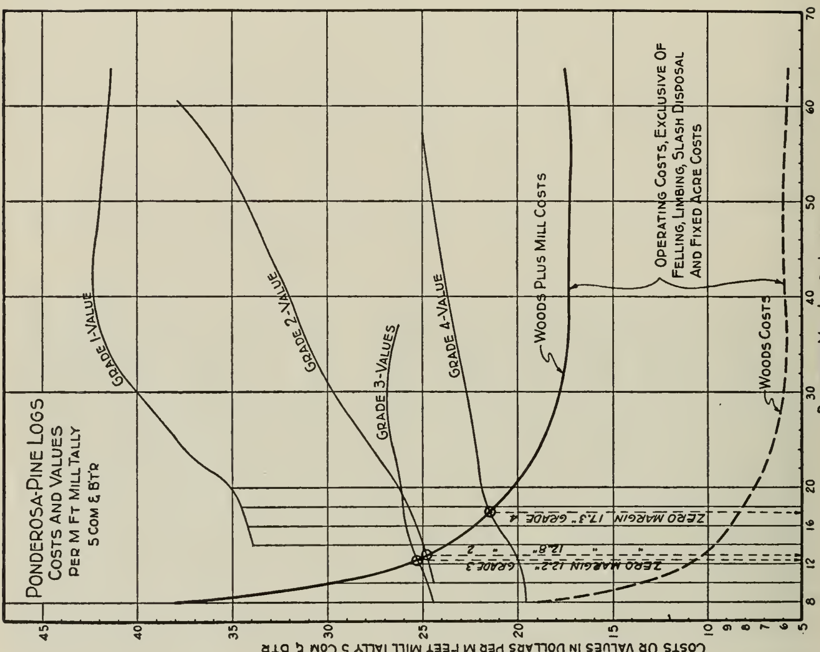
PONDEROSA-PINE LOGS
COSTS AND VALUES
PER M FT MILL TALLY
5 COM & BTR
GRADE 1-VALUE
GRADE 2-VALUE
GRADE 3-VALUES
GRADE 4-VALUE
WOODS PLUS MILL COSTS
OPERATING COSTS, EXCLUSIVE OF FELLING, LIMBING, SLASH DISPOSAL AND FIXED ACRE COSTS
WOODS COSTS
ZERO MARGIN 17.3" GRADE 4
" 12.8" " 2
ZERO MARGIN 12.2" GRADE 3
COSTS OR VALUES IN DOLLARS PER M FEET MILL TALLY 5 COM & BTR
DIAMETER MILL LOGS - INCHES

Fig. 13

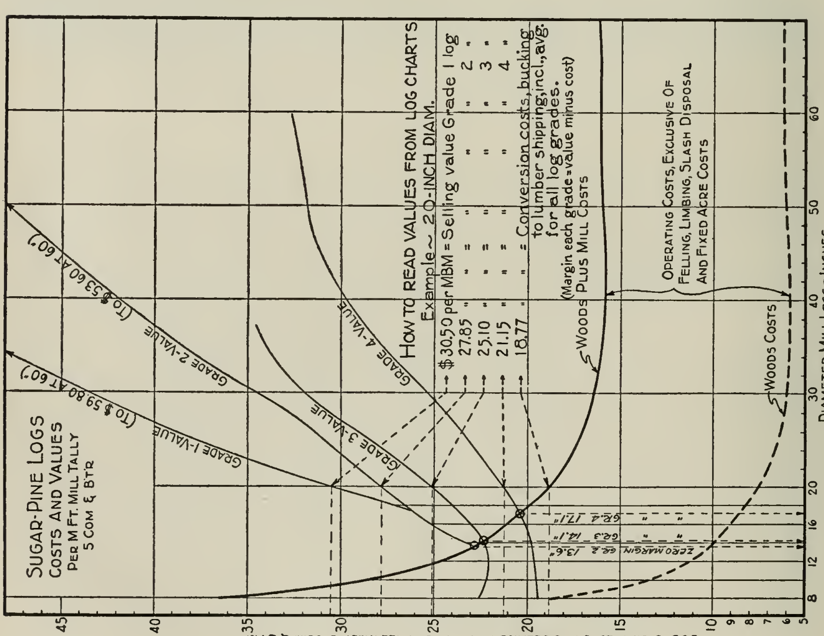
SUGAR-PINE LOGS
COSTS AND VALUES
PER M FT. MILL TALLY
5 COM & BTR
(TO $59.80 AT 60")
(TO $53.60 AT 60")
GRADE 1-VALUE
GRADE 2-VALUE
GRADE 3-VALUE
GRADE 4-VALUE
HOW TO READ VALUES FROM LOG CHARTS
Example ~ 20-INCH DIAM.
$30.50 per MBM = Selling value Grade 1 log
27.85 " " " " " 2 "
25.10 " " " " " 3 "
21.15 " " " " " 4 "
18.77 " " = Conversion costs, bucking to lumber shipping, incl., avg. for all log grades.
(Margin each grade = value minus cost)
WOODS PLUS MILL COSTS
OPERATING COSTS, EXCLUSIVE OF FELLING, LIMBING, SLASH DISPOSAL AND FIXED ACRE COSTS
WOODS COSTS
ZERO MARGIN GR. 2 13.6"
GR. 3 14.1"
GR. 4 17.1"
COSTS OR VALUES IN DOLLARS PER M FEET MILL TALLY 5 COM. & BTR.
DIAMETER MILL LOGS - INCHES

Fig. 12

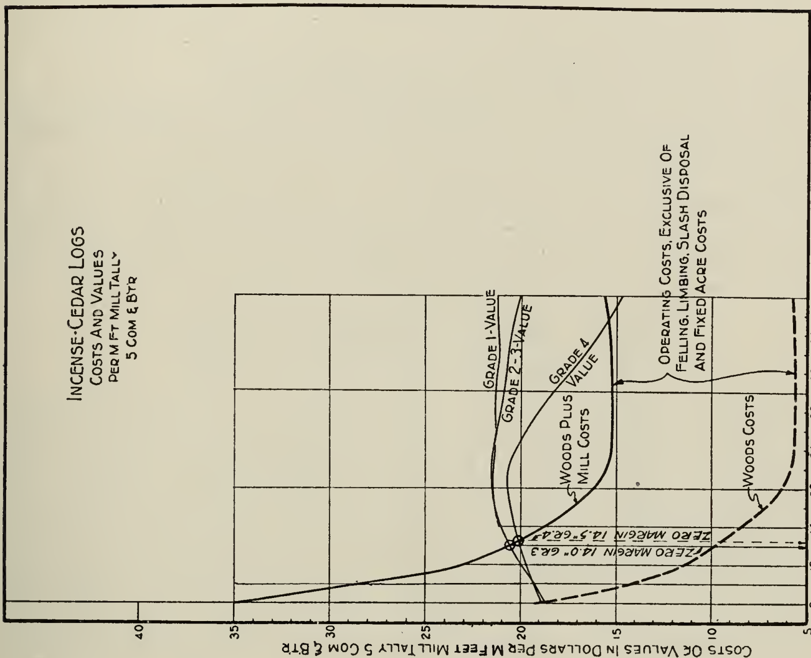
INCENSE-CEDAR LOGS
COSTS AND VALUES
PER M FT MILL TALLY
5 COM & BTR
GRADE 1-VALUE
GRADE 2-3-VALUE
GRADE 4 VALUE
WOODS PLUS MILL COSTS
OPERATING COSTS, EXCLUSIVE OF FELLING, LIMBING, SLASH DISPOSAL AND FIXED ACRE COSTS
WOODS COSTS
ZERO MARGIN 14.5" GR.4
ZERO MARGIN 14.0" GR.3
DIAM MILL LOGS-INCHES
8 12 16 20 24 28 32 36 40
COSTS OR VALUES IN DOLLARS PER M FEET MILL TALLY 5 COM & BTR
5 10 15 20 25 30 35 40

Fig. 15

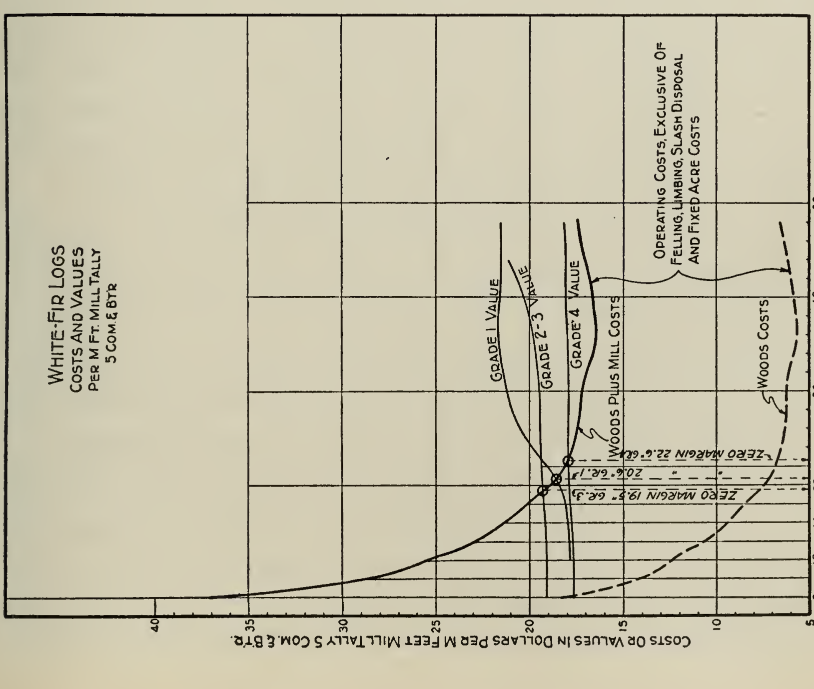
WHITE-FIR LOGS
COSTS AND VALUES
PER M FT. MILL TALLY
5 COM. & BTR
GRADE 1 VALUE
GRADE 2-3 VALUE
GRADE 4 VALUE
WOODS PLUS MILL COSTS
OPERATING COSTS, EXCLUSIVE OF FELLING, LIMBING, SLASH DISPOSAL AND FIXED ACRE COSTS
WOODS COSTS
ZERO MARGIN 22.6" GR.4
20.6" GR.1
ZERO MARGIN 19.5" GR.3
DIAMETER MILL LOGS-INCHES
8 12 16 20 30 40 50
COSTS OR VALUES IN DOLLARS PER M FEET MILL TALLY 5 COM. & BTR.
5 10 15 20 25 30 35 40

Fig. 14

Differences in total bucking-to-lumber-shipping costs per M.B.M. due to differences in diameter, as shown by the log cost curves and the summary in table 7, were very similar for all species.

Total costs per M.B.M., bucking to lumber shipping, inclusive, *more than doubled* with decrease in log diameter to 8 inches from an average of about 40 inches.

The increase in costs per M.B.M. was equivalent to an average of about 64 cents per inch of decrease between these sizes. The percentage of increase in costs per M.B.M., by 10-inch log diameter intervals, was:

3.6 per cent from 40 inches to 30 inches
14.2 per cent from 30 inches to 20 inches
51.9 per cent from 20 inches to 10 inches

Values per M.B.M. for Logs.—The selling values per M.B.M. of different species, grades, and sizes of logs may be read from the value curves in figures 12 to 15. They have not been recapitulated in tabular form because of the large number of segregations involved. Curved values in the sugar-pine and ponderosa-pine charts are depreciated for seasoning degrade only to the extent determined from the rough-dry inspections described previously under "Lumber Depreciation," page 23. Additional deductions on account of surfacing, stain, and storage degrade, based on other depreciation studies in the pine region, are given in table 8. Adjustments to compensate for the absence of carrying charges on air-dried sugar pine Selects and Shops (see "Adjustment of Sugar Pine Seasoning Costs," page 27) so the comparison between sugar-pine and ponderosa-pine margins will be valid, have been incorporated with the data in table 8. These latter adjustments are practically equivalent to the application of kiln-drying costs to all sugar-pine uppers.

It is evident from the selling-value curves (figs. 12–15) that the greatest variations in value per M.B.M. with differences in log diameter occurred in sugar pine, the least in white fir. With a few exceptions the variations were continuous decreases in value from large to small sizes. The only exception of any real significance from the economic standpoint was found in incense cedar, where the maximum value for grade 4 logs occurred at about 22 inches and from this point decreased more rapidly with increase in diameter than with decrease in diameter.

Zero-Margin Diameters for Logs.—Where the "Woods Plus Mill Cost" curves cross the log-value curves, production cost and selling value are equal. The sizes where this occurs may be read from the lower chart scales by following the vertical lines extended downward from the points of intersection in figures 12, 13, 14, and 15. Since value minus cost for these diameters was zero, they are termed the "zero-margin

TABLE 8

DEDUCTIONS PER M.B.M. FOR SURFACING, STAIN, AND STORAGE DEGRADE:* TO BE TAKEN FROM CURVED VALUES FOR SUGAR-PINE AND PONDEROSA-PINE LOGS

Mill-log diameter in inches	Log grades 1	2	3	4
	Sugar-pine logs			
10	....	....	$0.00	$0.00
14	....	....	0.00	0.00
16	....	$0.10	0.22	0.00
18	$0.20	0.35	0.50	0.00
20	0.70	0.61	0.90	0.30
26	2.18	1.60	1.70	1.35
30	2.75	2.18	1.99	1.80
40	3.58	3.00	2.55	2.25
50	3.99	3.57	....	2.50
60	4.18	3.85	....	2.60
70	4.25	3.94	....	....
	Ponderosa-pine logs			
10	....	....	0.00	0.00
14	....	0.00	0.00	0.00
16	1.41	0.30	0.37	0.00
18	1.52	0.58	0.60	0.00
20	1.60	0.75	0.88	0.25
26	1.81	1.26	1.38	0.82
30	1.98	1.52	1.59	1.10
40	2.10	1.88	$1.75	1.35
50	2.19	2.05	....	1.40
60	$2.19	$2.20	....	$1.39

*Including adjustments of comparative seasoning costs. See "Additional Depreciation of Pine Species," page 25, and "Adjustment of Sugar Pine Seasoning Costs," page 27.

diameters" and represent the sizes which just paid their way after the trees were felled and limbed. These zero-margin sizes are recapitulated in table 9.

Log length as bucked prior to skidding is, of course, an important factor affecting woods costs per M.B.M. All results expressed in terms of the mill-log-diameter variable alone, therefore, are necessarily subject to change with any changes in the basic woods lengths involved in the calculations. Roughly, the average woods length for the diameters shown in table 9 was between 26 and 28 feet. On a woods-log basis, logs smaller in diameter than the zero-margin sizes given in table 9 will "break even" if they are longer than this average length. If shorter, the zero-margin diameters will be somewhat greater. The diameter factor

alone does not provide an exact index of marginal values, but it is reasonably satisfactory as a basis for showing the general trends of size-margin relations.

TABLE 9

ZERO-MARGIN LOG DIAMETERS ON THE STANISLAUS STUDY AREA

Log grade	Sugar pine	Ponderosa pine	White fir	Incense cedar
	Diameter small end, inches			
1	........*	........*	20.6	........*
2	13.6	12.8	........†	........†
3	14.1	12.2	19.5	14.0
4	17.1	17.3	22.6	14.5‡

* All sizes profitable. Grade-1 logs are rarely found smaller than 20 inches in the west-slope pine region.

† Shop-type logs were graded as No. 3 in fir and cedar.

‡ As shown in figure 15, there was also a *maximum* zero margin for grade-4 incense cedar logs at approximately 37.5 inches.

Log Margins.—For logs of diameters greater than the zero-margin sizes, the difference in dollars between "value" and "woods plus mill costs" curves in figures 12, 13, 14, and 15, represents the sum per M.B.M. available from the selling value of each diameter class and log grade—after deducting all costs incurred between bucking and shipping—for:

1. Fixed acre costs
2. The expense of felling and limbing
3. Slash disposal costs
4. Stumpage
5. Interest and profit
6. In the two pine species only, additional losses from surfacing, stain, and storage degrade.

The margins for pine logs, after making the value corrections called for by item 6 above, are given in table 10. White-fir and incense-cedar curved values need no further adjustment.

The margins in table 10 and the margins for white-fir and incense-cedar logs obtained by reading the differences between the cumulative bucking-to-lumber-shipping cost curves ("woods plus mill costs") and the value curves in figures 14 and 15, show that decreasing values through the lower diameter range, combined with increasing costs, resulted in cash losses ranging from a few cents to almost twenty dollars per M.B.M. in the small sizes, *the greatest net losses being incurred on the logs of very small diameters, which are cut principally from the smaller sizes of trees.*

TABLE 10

CORRECTED MARGINS* PER M.B.M. FOR SUGAR-PINE AND PONDEROSA-PINE LOGS

Mill-log diameter in inches	Log grade 1	2	3	4
	Sugar-pine logs			
10	....	....	−$6.36†	−$8.96†
14	....	....	− 0.08†	− 2.68†
16	....	$ 4.14	1.67	− 1.01†
18	$ 6.51	6.36	3.56	0.81
20	10.83	8.42	5.53	2.43
26	19.61	12.74	10.49	5.14
30	24.12	15.89	13.53	7.12
40	33.61	22.94	16.59	11.54
50	37.79	28.36	....	13.38
60	39.52	33.40	....	13.75
70	42.30	36.89	....	....
	Ponderosa-pine logs			
10	....	− 5.43†	− 5.05†	−10.20†
14	....	1.23	1.83	− 3.37†
16	10.40	2.64	3.11	− 1.31†
18	11 76	3.90	4.17	0.32
20	13.17	5.26	5.03	1.38
26	18.04	8.61	6.90	3.08
30	20.20	10.30	7.41	3.78
40	22.89	12.76	$ 6.52	4.95
50	22.54	14.95	....	5.78
60	$21.95	$18.07	....	$ 6.45

* Margins per M. B. M. mill tally No. 5 Common and Better obtained by deducting "woods plus mill costs" as shown in figures 12 and 13, from log-grade values in the same figures, and then reducing these further by the amounts given in table 8. The margins in this table, therefore, are corrected for all types of lumber depreciation and incorporate seasoning cost adjustments.

† Minus sign indicates operating loss.

TREE COSTS, VALUES, AND MARGINS

Relation of Tree Diameter to Lumber Grades Produced.—On page 19, the proportions of the total gross scale of trees in the different log grades were briefly outlined as an index of timber quality on the study area. This hardly conveys an adequate picture of the reason for tree-value fluctuations, however, for logs of the same grade also fluctuate in value with changes in size. Differences in yield of the various grades of lumber from different sizes of trees are the real basis of value increases and decreases.

In the calculations of log and tree values for the study, there were 50 segregations in sugar pine, 40 in ponderosa pine, 18 in white fir, and 6 in

incense cedar for lumber grades and thicknesses. They are too numerous to be tabulated fully in relation to log and tree sizes, but if the thickness segregations are dropped, the lumber grades alone can be shown diagrammatically for average trees of each diameter and species so as to bring out forcefully the fundamental relations between outside size and inside quality.

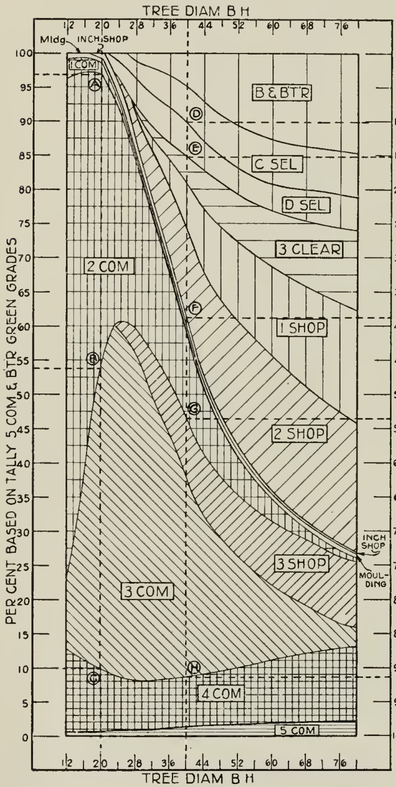

Fig. 16.—Green-lumber-grade production in sugar-pine trees.

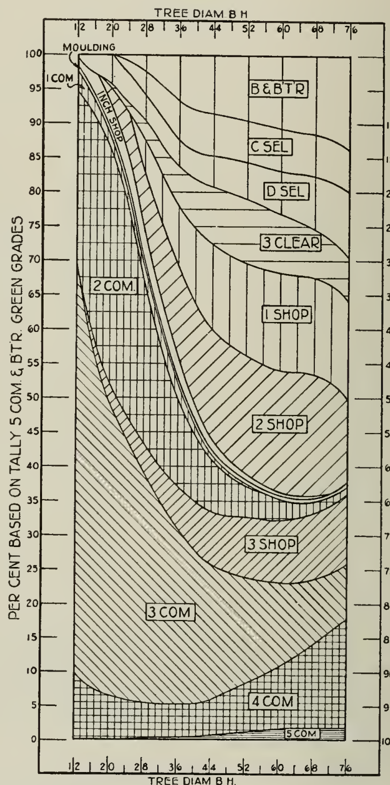

Fig. 17.—Green-lumber-grade production in ponderosa-pine trees.

Figures 16, 17, 18, and 19 show how green-lumber-grade production varied between the smallest and largest trees of each species on the study area. The space between top and bottom of the rectangular diagrams represents 100 per cent of the green-chain lumber production from average trees of the diameters noted on the scales above and below the rectangles. A vertical line extended through the diagram from any diameter will be divided into irregular intervals by the curved lines separating the various grades. Each of these intervals represents

the fractional percentage of the grade designated between the curved lines. The cumulative total percentage of all grades *below* any point where a vertical line crosses a curved line may be read directly by horizontal reference to the left-hand scale and that for all grades *above* such point, by reference to the right-hand scale.

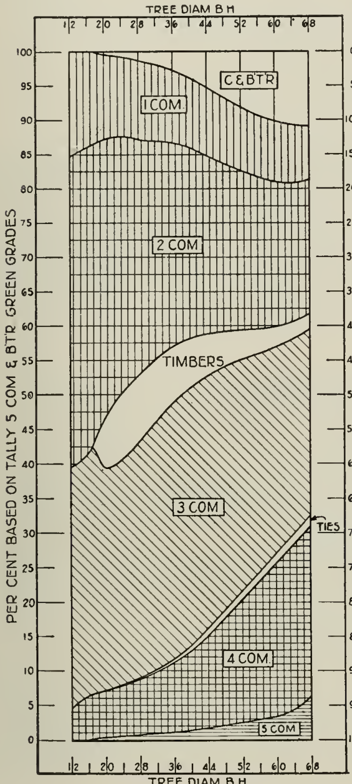

Fig. 18.—Green-lumber-grade production in white-fir trees.

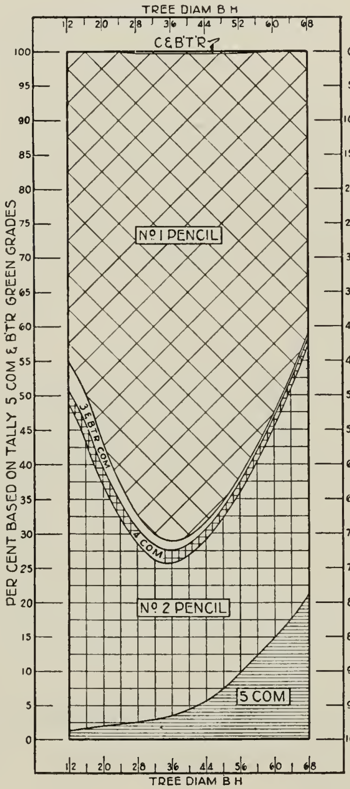

Fig. 19.—Green-lumber-grade production in incense-cedar trees.

Dotted lines have been extended vertically for 20-inch and 40-inch sugar-pine trees (fig. 16). Where these vertical dotted lines intersect some of the curved lines between lumber grades, horizontal dotted lines have also been extended to the left and right percentage scales, respectively. The letters in the small circles refer to these points of intersection. Sample readings, with reference to the designated points, are given below to illustrate how the approximate percentage of any particular grade or group of grades may be read from the figures for a given diameter of tree.

20-inch sugar-pine trees:

1,000 board feet of mill run lumber cut from this size is represented by vertical dotted line *A B C*.

All grades, Inch Shop to No. 5 Common, inclusive, = 100 per cent.

By reference to the left-hand scale:

A = 97 per cent of No. 2, No. 3, No. 4, and No. 5 Common, combined.
B = 54 per cent of No. 3, No. 4, and No. 5 Common.
C = 10 per cent of No. 4 and No. 5 Common.

Deducting *B* from *A* : 97 – 54 = 43 per cent of No. 2 Common.

Deducting *C* from *B* : 54 –10 = 44 per cent of No. 3 Common.

If point *B* is projected by eye to the right-hand scale, the reading is 46 per cent from top of chart, meaning 46 per cent in the grades of No. 2 Common and Better. Reading point *A* on the right-hand scale gives 3 per cent in the grades of No. 1 Common, Inch Shop, and Molding combined.

40-inch sugar-pine trees:

Line *D E F G H*, referred to right-hand scale:

D = 10 per cent of C Select and Better.
E = 15 per cent of D Select and Better.
  E – *D* = 15 per cent – 10 per cent = 5 per cent of D Select alone.
F = 39 per cent of No. 2 Shop and Better.
  F – *E* = 39 per cent –15 per cent = 24 per cent of No. 3 Clear, No. 1 and No. 2 Shop, combined.
G = 53½ per cent of No. 2 Common and Better.
H = 91½ per cent of No. 3 Common and Better.

Reading point *H* from the left-hand scale shows approximately 9 per cent of the lumber from 40-inch trees in the grades of No. 4 and No. 5 Common combined—8½ per cent if the reading is taken more accurately.

Interpolation of exact values was not anticipated in constructing the diagrams, however. The object of combining the grades in this manner was, rather, to reduce detailed tabular data for each species to a compact form enabling quick general comparisons between different sizes of the same species and between different species as a whole.

In white fir (fig. 18), the grade of C and Better increased from less than 1 per cent in 20-inch trees to 11 per cent in 68-inch trees, but No. 4 Common also increased from 6½ per cent to 20 per cent, and No. 5 Common from 0.6 per cent to 6 per cent. Thus the increase in low-value material tended constantly to counterbalance the increase in high-value material.

In incense cedar (fig. 19), 10/4 Pencil Stock was the principal product sought and the chart shows the results. There is an increasing amount of C and Better obtainable in the large trees but it is doubtful that any net gain would be made by sawing for it, as production costs would increase, while overrun and the percentage of No. 1 Pencil Stock would be reduced.

For sugar pine and ponderosa pine, the lumber-grade charts (figs. 16 and 17) show so clearly why selling values drop as diameters become smaller that any added comment would be superfluous.

Relation of Tree Diameter to Felling and Limbing Costs.—It is not enough to use merely the log margins as a guide in determining the size of the smallest tree which will just pay its way. To the cost of making the logs and converting them into lumber must be added the costs of felling and limbing—not a camp-average cost but the prorated cost for each size based on the time per M.B.M. spent by the fellers and limbers in chopping, sawing, wedging, and trimming any particular class of trees.

It took a very short time to fell and limb 12-inch trees and a long time to fell and limb 80-inch trees, but the time spent on the 80-inch tree produced 16,100 feet B.M. gross scale of saw logs, while that spent on the 12-inch tree produced but 50 feet B.M. In terms of dollars and cents, the felling and limbing of the 12-inch tree cost $0.53 and the 80-inch tree cost $8.76, including prorated bull buck's time, camp overhead, and tools. But, on an M.B.M. basis, felling and limbing 1 M.B.M. log scale from 12-inch trees cost $10.60 and the same volume from 80-inch trees cost $0.54. Relative costs for other sizes, on an M.B.M. mill-tally basis, are given in table 11.

Felling and limbing costs per M.B.M. mill tally for sugar pine *increased,* with decrease in tree diameter:

$0.05 from 60 to 50 inches
0.08 from 50 to 40 inches
0.18 from 40 to 30 inches
0.97 from 30 to 20 inches
$7.51 from 20 to 12 inches

Those operators who do felling and limbing by contract may be inclined to discount these increases because they are based on day-wage labor. Granting that contract labor will cut more timber in a day, there is, nevertheless, an inevitable decrease in output per man-hour as the trees cut become smaller, which amounts, in the last analysis, to the same thing as an increase in cost per M.B.M. The *rate* of increase, therefore, is significant.

This rate of increase per M.B.M. may be expressed in various ways. On a percentage basis, the increase in felling and limbing costs for sugar-pine trees was 25.5 per cent with decrease in tree diameter from 60 inches to 40 inches; from 40 inches to 20 inches, the increase was 180 per cent; and from 20 inches to 12 inches the increase was 420 per cent.

TABLE 11

Cost per M.B.M. of Felling and Limbing Sugar-Pine Trees

Tree diameter inches	Cost per tree	Mill-tally volume utilized, in feet B. M.	Cost per M. B. M. green-chain tally
12	$0.530	57	$9.30
14	0.541	90	6.01
16	0.549	145	3.79
18	0.574	224	2.56
20	0.590	329	1.79
22	0.627	457	1.37
24	0.678	613	1.11
26	0.747	781	0.96
28	0.829	960	0.86
30	0.929	1,130	0.82
40	1.674	2,634	0.64
50	2.772	4,950	0.56
60	$4.214	8,242	$0.51

The cost per M.B.M. mill tally for felling and limbing 18-inch sugar-pine trees in this study was four times as much, and for 12-inch trees it was fourteen and a half times as much, as the cost of felling and limbing 40-inch trees.

Results for other species were similar to those for sugar pine. Actual costs for any diameter of any species may be read from the bottom curves in figures 20, 21, 22, and 23.

Cumulative Costs for Trees.—With felling and limbing costs for each species prorated to tree sizes, the next step is to add on all other costs, except fixed acre expense, based on the log sizes in each d.b.h. class and arrive at the total costs per M.B.M. correlated with tree diameters.

The cumulative curves in figures 20, 21, 22, and 23 show how such combining of costs worked out for each species on the study area. The value curves in the same diagrams enable ready comparison between cost and value for any particular tree diameter. The only difference between the figures for logs (figs. 12–15) and those for trees (figs. 20–23) is that felling and limbing costs are included in the latter and omitted from the former. A sample reading is given for the average 28-inch sugar-pine tree in figure 20.

Cumulative costs for trees of different species and diameters are recapitulated in table 12. The amounts show the total expenditures per M.B.M. from felling to lumber-shipping inclusive. They do not include fixed-acre costs, slash disposal, or stumpage. The costs for each species are identical with those plotted for the same diameters in the "cumulative-cost" curves of figures 20 to 23.

TABLE 12

Relative Costs per M.B.M.* for Trees of Different Diameters

Tree diameter, inches	Sugar pine	Ponderosa pine	Sugar pine and ponderosa pine, average†	White fir	Incense cedar
14	$39.78	$37.57	$38.67	$31.94	$43.66
16	31.94	32.38	32.16	27.84	36.79
18	27.99	29.18	28.58	25.74	31.42
20	25.65	26.77	26.21	24.40	27.66
30	20.29	21.32	20.80	19.91	19.83
40	18.04	19.29	18.66	18.36	17.39
50	17.01	18.25	17.63	17.54	16.60
60	16.61	17.94	17.27	$17.55	$16.82
70	$16.59	$17.85	$17.22	....	....

* Felling to lumber-shipping inclusive. Costs are on an M. B. M. mill-tally basis, No. 5 Common and Better.

† Unweighted averages to compensate for fictitious differences in air-drying and kiln-drying costs and for probably exaggerated differences in small-tree costs because of the scarcity, and consequent inadequate sampling, of small ponderosa-pine trees on the study area.

A comparison of costs by tree diameter and species shows that cumulative costs per M.B.M. mill-tally for trees 20 inches in diameter and under were highest in incense cedar and lowest in white fir. For the larger sizes, incense-cedar costs were somewhat less than those for white fir and also less than average costs for the two pine species combined.

The average cumulative costs for sugar pine and ponderosa pine show that *lumber from 14-inch trees cost more than twice as much per M.B.M. to produce as lumber from 40-inch trees.* With decrease in tree diameter from 40 inches to 20 inches the increase in operating costs per M.B.M. was about 40 per cent, but from 40 inches to 14 inches, the increase was slightly more than 107 per cent.

Values per M.B.M. for Trees.—The curved values per M.B.M. for sugar-pine and ponderosa-pine trees (figs. 20 and 21) like those for logs, are discounted only for seasoning depreciation based on the rough-dry inspections of the summer-dried Shop and Better study lumber. Additional deductions for depreciation from surfacing, storage, and stain, and adjustment of seasoning cost differences must be made so that the values will be representative of average realizations obtained

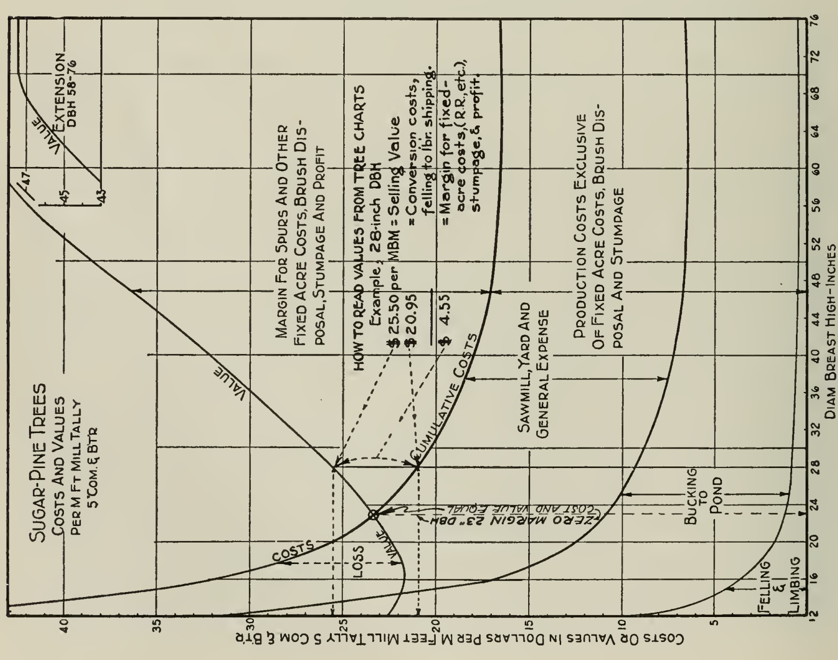
SUGAR-PINE TREES
COSTS AND VALUES
PER M FT MILL TALLY
5 COM. & BTR
VALUE EXTENSION DBH 58-76
47
45
43
MARGIN FOR SPURS AND OTHER FIXED ACRE COSTS, BRUSH DISPOSAL, STUMPAGE AND PROFIT
HOW TO READ VALUES FROM TREE CHARTS
Example, 28-inch DBH
$ 25.50 per MBM = Selling Value
$ 20.95 = Conversion costs, felling to lbr. shipping.
$ 4.55 = Margin for fixed-acre costs, (R.R., etc.), stumpage, & profit.
VALUE
CUMULATIVE COSTS
COSTS
LOSS
SAWMILL, YARD AND GENERAL EXPENSE
PRODUCTION COSTS EXCLUSIVE OF FIXED ACRE COSTS, BRUSH DISPOSAL AND STUMPAGE
COST AND VALUE EQUAL
ZERO MARGIN 23" DBH
BUCKING TO POND
FELLING & LIMBING
DIAM BREAST HIGH-INCHES
COSTS OR VALUES IN DOLLARS PER M FEET MILL TALLY 5 COM & BTR

Fig. 20

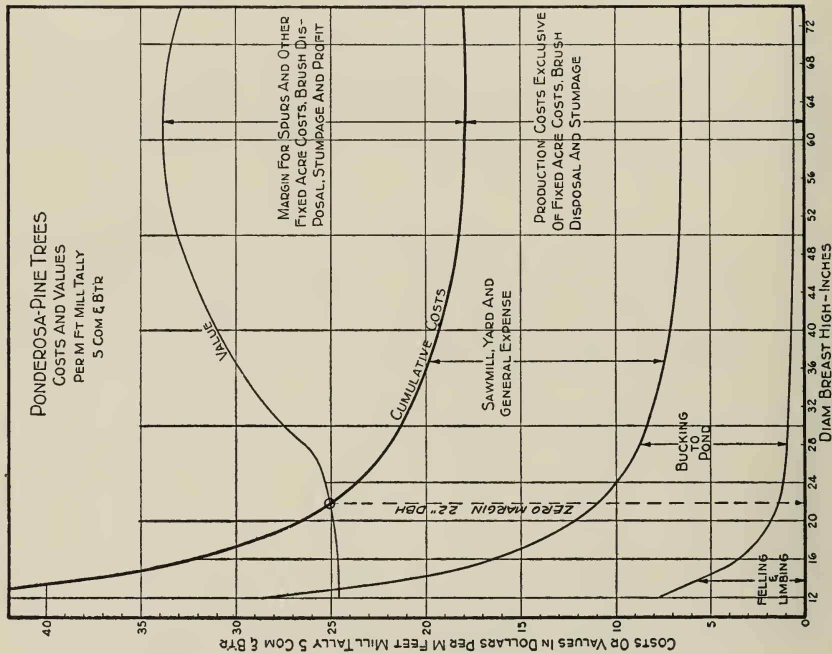
PONDEROSA-PINE TREES
COSTS AND VALUES
PER M FT MILL TALLY
5 COM & BTR
MARGIN FOR SPURS AND OTHER FIXED ACRE COSTS, BRUSH DISPOSAL, STUMPAGE AND PROFIT
PRODUCTION COSTS EXCLUSIVE OF FIXED ACRE COSTS, BRUSH DISPOSAL AND STUMPAGE
VALUE
CUMULATIVE COSTS
SAWMILL, YARD AND GENERAL EXPENSE
BUCKING TO POND
ZERO MARGIN 22" DBH
FELLING & LIMBING
DIAM BREAST HIGH-INCHES
COSTS OR VALUES IN DOLLARS PER M FEET MILL TALLY 5 COM & BTR

Fig. 21

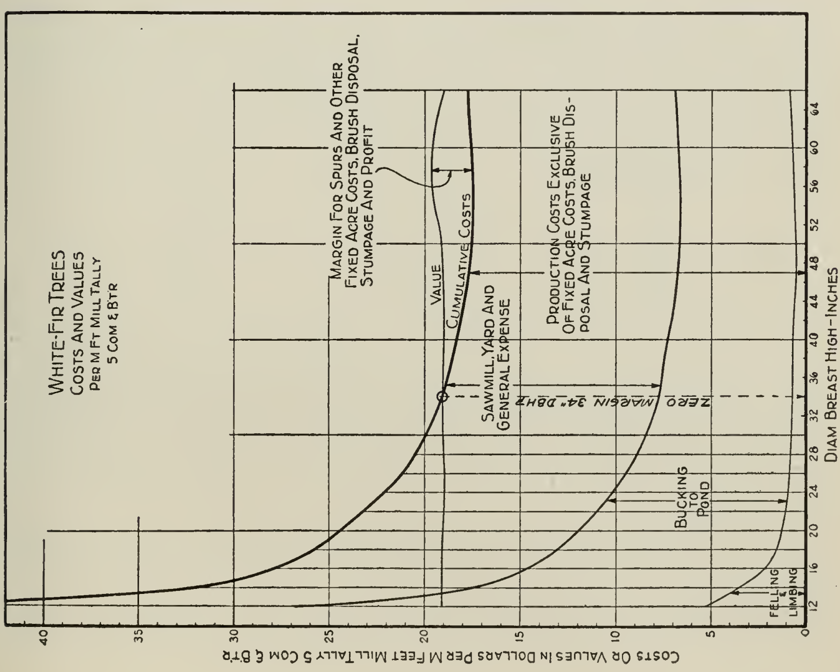
WHITE-FIR TREES
COSTS AND VALUES
PER M FT MILL TALLY
5 COM & BTR
MARGIN FOR SPURS AND OTHER FIXED ACRE COSTS, BRUSH DISPOSAL, STUMPAGE AND PROFIT
VALUE
CUMULATIVE COSTS
SAWMILL, YARD AND GENERAL EXPENSE
PRODUCTION COSTS EXCLUSIVE OF FIXED ACRE COSTS, BRUSH DISPOSAL AND STUMPAGE
ZERO MARGIN 34" DBH
BUCKING TO POND
FELLING & LIMBING
COSTS OR VALUES IN DOLLARS PER M FEET MILL TALLY 5 COM & BTR
DIAM BREAST HIGH-INCHES
0
5
10
15
20
25
30
35
40
12
16
20
24
28
32
36
40
44
48
52
56
60
64

Fig. 22

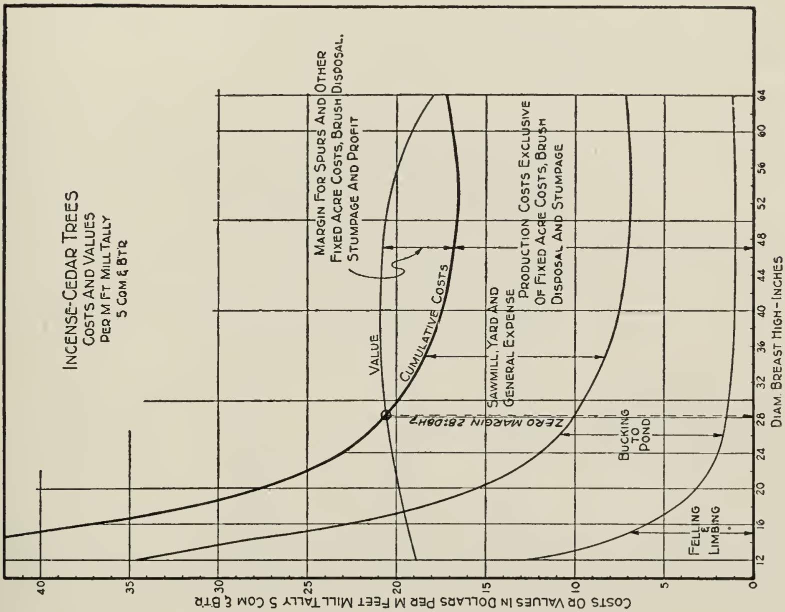
INCENSE-CEDAR TREES
COSTS AND VALUES
PER M FT MILL TALLY
5 COM & BTR
MARGIN FOR SPURS AND OTHER FIXED ACRE COSTS, BRUSH DISPOSAL, STUMPAGE AND PROFIT
VALUE
CUMULATIVE COSTS
SAWMILL, YARD AND GENERAL EXPENSE
PRODUCTION COSTS EXCLUSIVE OF FIXED ACRE COSTS, BRUSH DISPOSAL AND STUMPAGE
ZERO MARGIN 28" DBH
BUCKING TO POND
FELLING & LIMBING
COSTS OR VALUES IN DOLLARS PER M FEET MILL TALLY 5 COM & BTR
DIAM. BREAST HIGH-INCHES
0
5
10
15
20
25
30
35
40
12
16
20
24
28
32
36
40
44
48
52
56
60
64

Fig. 23

over a period of one or more seasons.[16] These affect principally the larger trees from which the Selects and upper Shop grades are cut. The corrections for tree values appear in table 13.

TABLE 13

Deductions per M.B.M. for Surfacing, Stain, and Storage Degrade* to be Taken from Curved Values for Sugar-Pine and Ponderosa-Pine Trees

Tree diameter, inches	Sugar pine	Ponderosa pine
20	$0.00	$0.00
22	0.00	0.10
24	0.00	0.38
26	0.35	0.53
28	0.66	0.70
30	1.00	0.83
40	1.97	1.39
50	2.52	1.60
60	3.03	1.80
70	3.40	$2.06
80	$3.45	....

* Including adjustments of comparative seasoning costs.

The following list of final average selling rices per M.B.M. for lumber from a few selected sizes of sugar-pine and ponderosa-pine trees shows the enhancement in values with increase in tree diameter from 14 inches to 60 inches after making the corrections given in table 13.

Tree Diameter, Inches	Sugar Pine	Ponderosa Pine
14	$21.93	$24.53
30	25.58	26.59
40	30.18	29.54
60	40.76	31.98

From these results, it is evident that lumber from 14-inch sugar-pine trees was worth 46 per cent less, per M.B.M., than lumber from 60-inch trees, and 27 per cent less than lumber from 40-inch trees. Lumber from 14-inch ponderosa-pine trees was worth 23 per cent less, per M.B.M., than lumber from 60-inch trees, and 17 per cent less than lumber from 40-inch trees.

There was little change in the M.B.M. value of white-fir trees of different diameters, the reason for which has been explained under "Relation

[16] See "Additional Depreciation of Pine Species" and "Adjustment of Sugar-Pine Seasoning Costs," pages 25 and 27, for explanation of these correction factors.

of Tree Diameter to Lumber Grades Produced," page 41. Incense-cedar lumber declined in value with increase in tree diameter above 50 inches somewhat more sharply than with decrease in tree diameter below 30 inches. The ravages of incense-cedar dry rot, entering mostly through fire scars on the butts of trees and increasing rapidly with increasing age, were responsible for the reversion. Between 30-inch and 50-inch diameters, the mill-run values were very nearly the same.

Zero-Margin Diameters for Trees.—The diameters breast high, measured outside the bark, of trees which just paid back the costs from felling to lumber shipping, with nothing left from the selling value to pay for stumpage or fixed acre expense, were:

Sugar pine	23 inches
Ponderosa pine	22 inches
White fir	34 inches
Incense cedar	28 inches

These are the zero-margin tree diameters designated in figures 20 to 23 by the dotted lines extended to the lower scales from the points of intersection of the "cumulative cost" curves with the "value" curves. To the left of these points, the cost curves rise very rapidly. The losses per M.B.M. incurred on lumber from trees below the zero-margin diameters may be derived approximately from the left-hand dollar scales by deducting the scale reading for "value" from the scale reading for "cumulative cost" directly above any given diameter on the lower scale.

Tree Margins.—The margins for white fir and incense cedar left from selling values after costs from felling to lumber shipping have been deducted may be read for any tree size from figures 22 and 23. No corrections are necessary for further depreciation.

The maximum average margin for white fir was $2.17 per M.B.M. on lumber from 56-inch trees. In 40-inch trees the margin was $0.69. There was a loss of $8.76 per M.B.M. on the lumber from 16-inch trees, and a loss of $12.84 on 14-inch trees.

Incense cedar was somewhat better in the middle sizes, with a maximum margin of $4.08 per M.B.M. on lumber from 48-inch trees. Going up the diameter scale, the margin fell to $0.73 on 64-inch trees, owing to cull. Down the scale, the margin on 40-inch trees was $3.51, and in 30-inch trees, $0.81 per M.B.M. The loss on 16-inch trees was $17.38, and on 14-inch trees the loss jumped to $24.47. The very small volumes in incense-cedar trees below 20 inches d.b.h. accounts for the fact that losses in the smallest sizes are so much greater than the losses on corresponding sizes in the white fir.

The pine margins, after adjusting in accordance with table 13, differ by varying amounts from the chart margins. Table 14 lists the corrected values for different d.b.h. classes.

TABLE 14

Corrected Margins* per M.B.M. for Sugar-Pine and Ponderosa-Pine Trees

Tree diameter, inches	Sugar pine	Ponderosa pine
14	−$17.85†	−$13.04†
16	−10.33†	− 7.78†
18	− 6.19†	− 4.48†
20	− 3.25†	− 1.96†
24	1.05	1.23
30	5.29	5.27
40	12.14	10.25
50	18.97	13.19
60	24.15	14.04
70	27.41	$13.49
80	$27.34	....

* Margins per M. B. M. mill tally No. 5 Common and Better obtained by deducting "cumulative costs," as shown in figures 20 and 21, from tree values in same figures and then reducing these further by the amounts given in table 13. The margins in this table, therefore, are corrected for all types of lumber depreciation and incorporate seasoning-cost adjustments.

† Minus sign indicates operating loss.

It is evident from figures 20 to 23, that the margins of both pine species go far above the white-fir and incense-cedar margins in the larger tree sizes, but it is also evident (table 14) that *these high margins in the large pine trees are very rapidly reduced as tree sizes become smaller.* Increasing costs and decreasing values per M.B.M. combined to change a ponderosa-pine value which was 53.1 per cent above costs for 40-inch trees to a loss of 7.3 per cent on 20-inch trees, and a loss of 34.7 per cent on 14-inch trees. A similar combination changed a sugar-pine value which was 67.3 per cent above costs for 40-inch trees to a loss of 12.7 per cent on 20-inch trees and a loss of 44.9 per cent on 14-inch trees.

CUTTING TO DIFFERENT MINIMUM TREE-DIAMETER LIMITS

Cutting to fixed tree-diameter limits irrespective of individual tree characteristics is not to be unqualifiedly recommended from either a forestry or a current-maximum-profit standpoint, although it is obvious that a minimum limit of 24 or 26 inches, for example, would leave west-slope cut-over lands in far better condition than the present 12 to 16-inch limits, and it is certain that operators would be rewarded by an immediate enhancement of net income. But no single tree-variable in a virgin

forest of mixed size-classes and mixed species can be isolated as an absolute index of relative future or present value. An operator managing his property as a permanent, sustained-yield unit will want to make the utmost from his capital investment in forest land. Stand improvement will be an objective of the cutting system adopted, as well as profitable current realization. His cutting instructions, therefore, should call for a certain degree of tree selection based on disease, deformity, insect infestation, stagnation due to overcrowding in heavily stocked groups, and other factors aside from tree size alone. Even if cutting exclusively for current profit with the idea of full liquidation and cessation of operation when all available virgin acreage has been cut over the first time, the operator-owner should recognize the desirability of some deviation above and below any *average* limits established by analysis of his own timber. The frequency of visible knots on the lower 16 to 24 feet of the bole is perhaps the most reliable index as a guide in judging whether a tree 2 or 3 inches larger than the average economic diameter limit should be left or whether a tree 2 or 3 inches smaller than the average economic limit can be profitably utilized.

But regardless of the short comings of mere diameter-limit cutting, an analysis of its effect on average costs, when fixed-acre expense is included in the total, is essential as a final revelation of the true significance of tree size in the west-slope lumbering operation studied.

In appraising the marginal value of a *log* after the tree is cut, limbed, and ready for bucking, only the costs incurred from that point on are deducted from the ultimate selling value of the log. In appraising the marginal value of a *tree* after railroads, camps, landings, etc., are installed, all log-conversion expense to be incurred by the logs in the tree, *plus* the felling and limbing costs, are deducted from the ultimate selling value of the tree. The tree must pay back all of these costs before anything can be contributed toward fixed acre expense. In appraising the average marginal value of a *woods-run mixture of trees of different species and sizes,* all of the tree and log costs, *plus* the fixed acre expense must be deducted from the average selling value of the mixture.

As a matter of efficient logging-operation planning, the costs treated as fixed costs per acre in this bulletin *should* vary per acre with the percentage of the stand cut. A heavy yield per unit of area calls for more railroad and shorter yarding distances. A light cut may come to the mill more economically with less railroad and longer yarding distances. They are left as a constant herein, however, both for simplification in presenting the comparative results of different cutting-diameter limits and for emphasizing the fact that even when a large expenditure is made for

railroad spurs, the operator can still reduce his average total costs per M.B.M. by leaving many small trees standing which he now thinks it profitable to bring in.

Figure 24 follows through, for each of seven different minimum tree-diameter cutting limits: (1) the volume in M.B.M. net scale cut per acre; (2) the number of trees between 12 inches d.b.h. and the minimum diameter limit which would be left per acre, without deductions for felling and logging losses[17]; (3) the fixed acre cost of $84.64 for railroads, camps, etc., spread over the net scale utilized when cutting to each limit; (4) the average conversion costs per M.B.M. net scale, which include all other costs except fixed acre expense; (5) the combined total costs per M.B.M. net scale, which are the sum of the fixed acre and conversion costs for each cutting limit; (6) the average selling value per M.B.M. net scale, discounted for lumber depreciation; (7) the average margin per M.B.M. net scale, obtained by deducting combined costs from selling values; and (8) the margin per acre, obtained by multiplying the average margin per M.B.M. net scale by the M.B.M. cut per acre.

As shown by the data and bar-diagrams in figure 24, cutting everything on the study plots to 12 inches d.b.h., inclusive, gives a yield of 53.2 M.B.M. net scale per acre. If 31 trees per acre from 12 to 35 inches d.b.h. are *not* cut, the yield will drop to 38.9 M.B.M.

The fixed acre cost of $84.64 must be charged off against whatever is cut, therefore it increases, on an M.B.M. basis, from $1.59 for the 12-inch limit to $2.18 for the 36-inch limit. But this is the only cost which does increase. Also the increase is small considering the big change in minimum cutting limit—it goes up only $0.59 per M.B.M., equivalent to an average increase of but 2½ cents for each inch of difference, between the 12 and 36-inch limits.

The much larger share of total production costs, designated as conversion costs per M.B.M. in the chart, steadily decreases as more and more of the smaller, high-cost trees are left uncut, i.e., high-cost in respect to felling, limbing, bucking, yarding, loading, log transportation, decking, and sawing. Costs for plant overhead, selling, shipping, etc., are included in the conversion costs but these have been treated in this report as fixed costs per M.B.M. The decrease in the average conversion cost, felling to lumber shipping, is $1.45 per M.B.M. when the cutting limit is raised from 12 inches to 36 inches d.b.h., which not only offsets

[17] The heavier the cut, the greater is the percentage of loss in the small-tree population left. With the 16-inch limit, the 10 trees per acre not cut, from 12 to 15 inches d.b.h. inclusive, as shown in figure 24, would be reduced by at least 50 per cent owing to breaking off by other trees in falling and to damage from yarding.

the $0.59 increase in fixed acre costs, but also gives an additional saving of $0.86 per M.B.M.

Midway between the 12 and 36-inch limits, cutting to a *24-inch limit* increases fixed acre costs by 12 cents per M.B.M. and decreases other costs by 85 cents per M.B.M., a net saving of 73 cents.

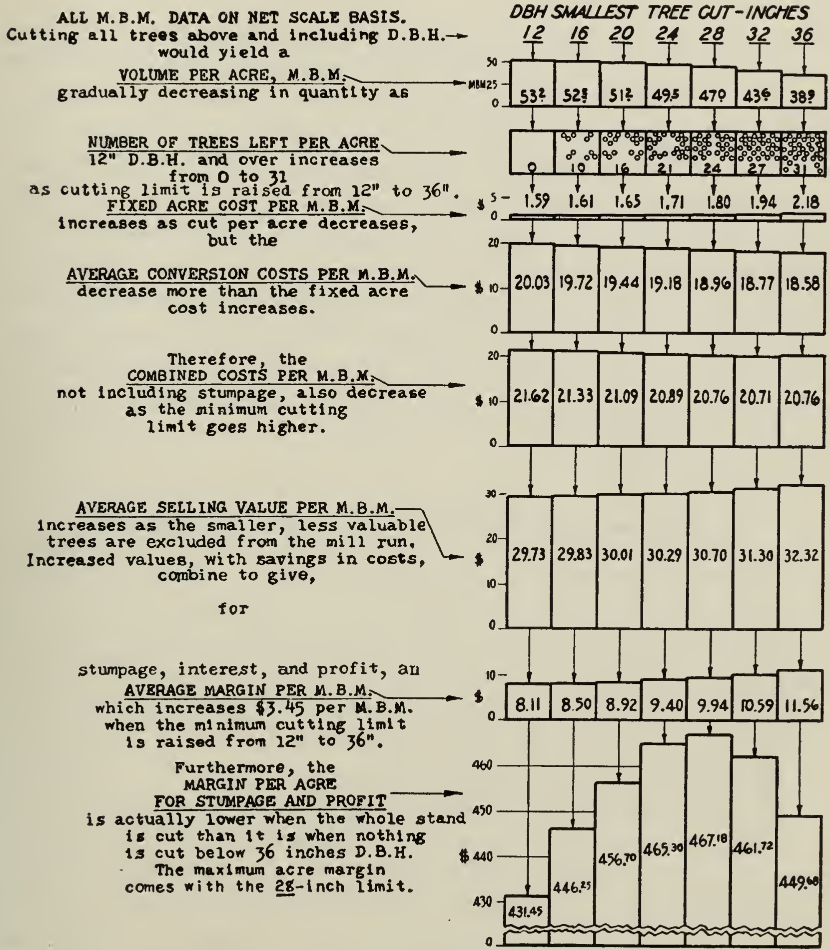

Fig. 24.—Effect of cutting to different d.b.h. limits on the Stanislaus study area.

The greatest saving in combined costs per M.B.M. comes with the 32-inch limit, which gives a net reduction of 91 cents per M.B.M. under the clear cutting (12-inch limit) costs.

The average selling value per M.B.M. net scale with the 36-inch limit increases $2.59 over the average of $29.73 yielded by 1 M.B.M. of mill-

run lumber from clear cutting. The increase would not be so large if the stand were pure ponderosa pine but it would be larger if the stand were pure sugar pine. Mixture of species in varying proportions for different diameter-breast-high classes unavoidably has an influence on average selling prices aside from the effect of change in cutting diameter limits.

Combining the savings in total operating costs with the rise in average value of the mill-run product, the average margin per M.B.M. jumps from $8.11 (12-inch limit) to $11.56 (36-inch limit). This is an increase of $3.45 in the margin per M.B.M. available for stumpage and profit.

The comparative heights of the bars at the bottom of figure 24 demonstrate conclusively the false economy of cutting to the customary 16-inch d.b.h. limit in virgin stands of the type studied. From the standpoint of profit per M.B.M. on the season's cut, there is a reduction in the average mill-run margin of $3.06 per M.B.M. from cutting 21 additional trees per acre in tree diameters below 36 inches and above 15 inches. *From the standpoint of profit per acre, there is a reduction of $20.93 in acre-margin from cutting 14 trees per acre below 28 inches and above 15 inches d.b.h.*

APPLICATION OF RESULTS TO OTHER OPERATIONS

Readers of this report may feel that it should close with recommendations for specific cutting systems. Unfortunately that cannot be done intelligently for a region or a subregion, since the cutting system best adapted to the needs of operator A may not be suitable for operator B. Just what trees to cut and what trees to leave depend on the operator's objectives, the size of the timber holdings he controls, the methods of logging used, the size of his mill, his market, and a dozen or more other factors concerning his own particular stand and his own local conditions.

But omission of details concerning what should and what should not be cut to comply with various objectives of management need not cause any operator in the west-slope region to hesitate about accepting the evidence herein given concerning the losses on small trees. Their low selling values come from the low lumber grades produced. These low grades result from their characteristic growth habit—full crowned, with green limbs still growing to the butt log and few to many dead limbs protruding through the bark all the way to the stump. The small trees on the study plot were typical of all small trees in the region, therefore their values are undoubtedly representative of small-tree values throughout the region.

Costs are also typical of the region for the type of logging studied. Regional averages were actually used for many items, and for those items necessarily based on the cooperating company's wage scales and expenditures for materials, the company averages were practically identical with regional averages. The item subject to greatest variation as between different operations is probably the fixed acre cost, but it should be remembered that this has no bearing on the zero-margin tree as defined in this report. The loss of $1.96 per M.B.M. on 20-inch ponderosa-pine trees and the loss of $3.25 per M.B.M. on 20-inch sugar-pine trees, shown in table 14, likewise were derived from calculations into which fixed acre costs did not enter.

Naturally, the cost per M.B.M. of producing lumber will vary with differences in wage scales, costs of material and supplies, etc., and the gross income will vary with differences in lumber selling prices. The low selling values of 1932 if applied in this study, would give lower tree values all along the line. Lower average costs would mean lower costs per M.B.M. for each tree size. If every lumber grade dropped exactly 40 per cent in value and every item of cost dropped exactly 40 per cent, the margins for fixed acre costs, stumpage, and profit shown in figures 20 to 23 would all be less for those diameters where values are greater than conversion costs, and by the same token the actual cash losses would be less for those diameters where values are less than conversion costs, but the zero-margin diameters would remain precisely where they are. On the other hand, if costs were decreased 30 per cent and the values of trees near the present zero-margin sizes dropped 35 per cent, the zero-margin diameters would be larger than those shown. For sugar pine, for example, such a combination would result in raising the zero-margin diameter from 23 inches to about 24½ inches. If the situation were to be reversed, with reduction in costs exceeding decline in value of the 1928–1930 zero-margin size, the latter would move down the scale. But so far, values have dropped by a greater percentage than production costs, so that the line of demarcation between the profitable and the unprofitable, i.e., the zero-margin limit, has shifted upward since the computations were made for this report.

It is true, of course, that margins on the same sizes of pines in other parts of the west-slope region and in the same type of timber may be more or less than those obtained in this study even under the same general schedule of prices, wages, and material charges; owing to differences in methods, equipment used, length of haul to mill, and so on. It is practically certain, however, that *every operation designed to handle and saw the big virgin timber found on the better areas of the western*

Sierra slopes is losing money on many of the smaller sizes of trees now being cut from private lands. It will be of very real economic benefit to such operators to raise their minimum cutting diameter limits for the pines considerably above the present 12 to 16-inch limits. That there would also be a tremendous improvement in the condition of private cut-over lands resulting from the widespread adoption of such changed practice is, of course, self-evident. But entirely apart from any forestry considerations whatever, *the leaving of small trees which do not pay their way is a practice which should be universally adopted by lumbermen purely on its merits as an operating economy.*

SUMMARY

A coordinated logging and milling study involving a typical virgin stand of Site-1, west-slope, California-pine-region timber, direct-tractor skidding, a 36-mile, standard-gauge-railroad log haul, and a double-band sawmill cutting about 80,000 M.B.M. per annum, was conducted in such a manner that costs and values could be determined separately for each species, size, and grade of logs and for each species and size of trees.

The stand studied contained a mixture of sugar-pine, ponderosa-pine, white-fir, and incense-cedar trees of all ages and sizes. The smallest tree of each species analyzed as to costs and value was 12 inches d.b.h. The largest was an 80-inch sugar pine. Maximum sizes of the other three species were: white fir and incense cedar, 64 inches d.b.h., ponderosa pine, 76 inches d.b.h. By volume, the original gross stand of approximately 59 M.B.M. per acre was made up of about 35 per cent white fir, 34 per cent sugar pine, 20 per cent ponderosa pine, and 11 per cent incense cedar.

The costs per M.B.M. of felling, limbing, bucking, yarding, loading, decking, unloading, and sawing increased as tree diameters decreased, the cumulative effect of these increases becoming so pronounced in the smallest d.b.h. classes that the total of all costs, variable and nonvariable, from felling to lumber shipping, inclusive, was approximately twice as much per M.B.M. for lumber from 14-inch trees as for lumber from 40-inch trees. Concurrently, values per M.B.M. decreased as tree diameters became smaller, the percentage of decrease being greatest in the pine species.

In all species, lumber from 40-inch trees was worth more than its production costs (excluding fixed-acre charges and stumpage) but lumber from average white-fir trees below 34 inches, average incense-cedar trees below 28 inches, average sugar-pine trees below 23 inches, and average

ponderosa-pine trees below 22 inches in breast-high diameter, was worth *less* than production costs. Average trees of the diameters noted yielded lumber of a value just sufficient to balance all costs except stumpage and fixed-acre charges. There being no margin for profit in utilizing trees of these sizes, they are termed the zero-margin diameters. The rate at which losses per M.B.M. increased below these diameters is indicated by the excesses of costs over values for 14-inch trees of each species. Based on average lumber selling prices and average costs for the period 1928–1930, inclusive, the *losses* per M.B.M. on lumber from average 14-inch trees were as follows: sugar pine, $10.33; ponderosa pine, $7.78; white fir, $12.84; incense cedar, $24.47.

For the stand as a whole, the maximum margin per acre would come, of course, from cutting every tree with a value equal to or greater than the felling-to-lumber-shipping costs, i.e., to the minimum zero-margin sizes given above. Disregarding species differences, the average minimum tree-diameter cutting limit to give the greatest margin per acre was 28 inches. Maximum margin per acre, however, is not analogous to maximum profit per M.B.M., or maximum profit on a season's cut. For a greater margin of profit on the investment and working capital, the minimum sizes of trees to be cut will usually be well above the zero-margin diameters on any area. For the stand studied, a minimum average cutting limit of 36 inches d.b.h. gave a net margin for stumpage, interest, and profit which was $1.62 per M.B.M. higher than the margin per M.B.M. obtained by cutting to the 28-inch average limit (i.e., for maximum margin per acre).

Just what cutting system will be best for a particular operator can only be determined from an analysis of the particular stand, the local situation, and the particular objectives of management. The results presented in this bulletin, however, may be regarded as reliable indicators of the approximate average tree diameters in the better Site-1 virgin stands of the west-slope region below which conversion costs become greater than the values recoverable. A small percentage of such submarginal trees should occasionally be cut for silvicultural reasons, but to cut them merely for increased volume per acre to reduce railroad construction costs per M.B.M. is wholly unjustified. This limit was above 20 inches d.b.h. on the study area even in the most valuable pine species. The larger operators in the west-slope pine region will find it good economy to raise their present minimum pine-tree diameter cutting limits from 12–16 inches to at least 22–24 inches. Still greater gains from the economic standpoint will be possible by raising the limit above 24 inches.

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When the yarding, loading, and sawmill studies were in full swing, some 35 men were required for study-crew duty (including day and night shifts in the mill). For the services of those individuals on the various crews who were not employed directly by the California Forest Experiment Station or the Division of Forestry of the University of California, the latter are indebted to the Region-5 Office of Forest Management, the Region-1 Office of Forest Products, the Stanislaus National Forest, the Sierra National Forest, and the Tahoe National Forest, of the Forest Service, United States Department of Agriculture; also the California White and Sugar Pine Manufacturers' Association (now merged with the Western Pine Association), and the cooperating lumber company mentioned above.

Although the results of their special studies are not included in this bulletin, cooperation of the following bureaus of the United States Department of Agriculture should also be acknowledged, viz., the San Francisco Office of Forest Pathology, Bureau of Plant Industry, and the Berkeley Office of Forest Insect Investigation, Bureau of Entomology. Summaries of their findings will appear in the proposed publication referred to in the footnote on page 10.

Many of the data collected were subjected to analysis from several different angles in order to work out the most satisfactory and reliable methods of computing and coordinating the numerous variables encountered. For this work, special credit is given to Ira J. Mason and Burnett Sanford, of the California Forest Experiment Station.

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